

# **An Inventory of California Driver Accident Risk Factors**

October 2003

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13. ABSTRACT (Maximum 200 words)  This report updates information on a random sample of licensed California drivers as published in an earlier report prepared by the California Department of Motor Vehicles: <i>An inventory of California driver accident risk factors</i> (Gebers & Peck, 1994). It is designed to provide highway safety administrators, insurance industry representatives, and researchers in the field of traffic safety with information for developing program and policy decisions. This report presents driver record information on a random sample of over 200,000 California drivers and driver record histories over varying time periods. The report addresses the following issues related to the assessment of traffic accident risk: <ul style="list-style-type: none"> <li>• Driver record in relation to gender and age.</li> <li>• Accident-repeater phenomenon.</li> <li>• Relationship between traffic accidents and citations.</li> <li>• Relationship between traffic accidents and multiple driver record variables (e.g., prior accidents and citations, sex, and license class).</li> <li>• Multiple logistic and negative binomial regression equations of accident risk factors and relativities.</li> </ul> Findings presented in the report confirmed that prior total citation frequency continues to be the most significant predictor of accident involvement, followed by prior accident involvement frequency. Increased accident involvement was shown to be associated with increased prior citation and accident frequencies, possessing a commercial driver license, being young, being male, having a medical condition on record, and having a physician referral for low visual-acuity on record.				
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The compilation is being published as a technical product of the Research and Development Branch rather than as a formal report of the State of California. As such, the opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the State of California.

## EXECUTIVE SUMMARY

### Background and Objective

- Since 1964, the California DMV has issued a number of monographs on driver characteristics and accident risk factors as part of a series known as the California Driver Record Study.
- The present report updates information presented in a 1994 departmental report. The compilation is based on a driver record file data extraction through 1998. Total sample size represents about 1% of all licensed drivers, or approximately 216,000 records. The specific sample sizes for the analyses vary depending on the type of analysis and the time intervals involved.
- The objective of the compilation is to provide driver license officials, epidemiologists, traffic safety researchers, and organizations involved in risk assessment and risk management with actuarial data on driver accident risk profiles.

### Findings

- Most drivers have very good records. Extremely deviant records are quite rare; fewer than 1% of the California driving population are classified as prima facie negligent drivers (four or more points in 12 months, six or more points in 24 months, or eight or more points in 36 months).
- Men have poorer records than do women, largely because men drive more miles.
- For both sexes, driver age is related to accidents and citations. Teen drivers have the highest accident-involvement and citation rates. As drivers age, their accident-involvement rate decreases through about age 69 and then increases somewhat. As drivers age, their citation rate decreases substantially.

- Accident risk increases as a function of the number of accidents and citations on the driver's prior record. Of the two, prior citations count is slightly superior as an indicator of subsequent accident risk.
- Subsequent accident risk can be more accurately predicted from a combination of prior accident and prior citation information than from either alone.
- Use of a longer period for counting prior incidents increases the accuracy of accident-risk prediction.
- The inclusion of traffic violator school dismissals in the prior citation counts results in increased accuracy of accident-risk assessment.
- Contrary to intuition, the number of total accidents (irrespective of culpability) is a better indicator of subsequent accident risk than are culpable accidents.
- Negligent-operator (neg-op) points are slightly better predictors of future accident risk than are prior accidents and prior citations. This relationship provides support for the department's neg-op point system, which triggers license control actions based on a driver's point count.
- In contrast to prior non-major citations, prior major citations (e.g, DUI's and reckless driving) and subsequent accidents do not consistently display a monotonic relationship. This implies that repeat major-citation offenders represent lower risks than one-time offenders. However, sanctions such as jail and license suspension likely function as deterrents, thereby reducing the intrinsic risk associated with repeat drunk-driving offenders.
- The relationships between citations and accidents occurring over the same (concurrent) time period are stronger than those for nonconcurrent time periods.
- Accident risk is a complex function of many variables necessitating the use of multivariate prediction models.
- Application of multiple regression analysis confirmed that prior total citation frequency continues to be the most significant predictor of accident involvement, followed by prior accident involvement frequency. Increased accident involvement was shown to be associated with increased prior citations and accident frequencies, possessing a commercial driver license, being young, being male, having a medical condition on record, and having a physician referral for low visual-acuity on record.

The results from the interaction regression model examining subsequent total accident involvement for young and older drivers with differing counts of prior driver record incidents warrant an examination of the viability of applying age-mediated traffic safety treatments to high-risk driver groups currently not receiving any form of driver safety intervention.

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## INTRODUCTION

The California Driver Record Study Database was created in 1962 and resulted in a 9-volume report series published between 1964-1967. That report series, known as the *1964 California Driver Record Study*, was summarized in a paper published in *Accident Analysis and Prevention* (Peck, McBride, & Coppin, 1971). Two earlier reports based on informal sampling and tallies of driver record information were produced in 1954 and 1958 (California Department of Motor Vehicles, 1958).

The original database consisted of a 2% systematic random sample of the California Driver License (DL) Master File and represented all drivers with DL numbers ending with 00 or 01. The sampling ratio was subsequently reduced to 1% (terminal digits 01), and the original manual process was completely automated when California automated its DL file in 1965.

The California Driver Record Study has three primary applications:

1. Operational planning
2. Basic descriptive research
3. Multivariate analysis of driver performance indicators

The main thrust of application 3 has been the identification of accident-risk correlates, the pursuit of which has guided much of the subsequently published reports and updated file extractions (Gebers, 1999; Gebers, 1998; Gebers & Peck, 2003a, b; Kuan, Peck, & Janke, 1990; Kwong, Kuan, & Peck, 1976; Peck & Gebers, 1992; Peck & Kuan, 1983).

The emphasis on accident risk emanates from both epidemiologic and risk management considerations, as described in several prior papers and monographs (e.g., Peck, 1993). The California Department of Motor Vehicles has the responsibility of licensing drivers and controlling driver accident risk through a variety of licensure and post-license control programs. A methodology for assessing accident risk and identifying high-risk drivers is an essential component of risk management and the optimization of driver-control functions.

In addition to identifying high-risk target groups for safety reasons, the isolation of accident-risk factors has other applications, most notably establishing casualty insurance premium structures. California Driver Record Study data have been used repeatedly by the insurance industry in establishing risk-based merit rating systems.

The present report is an update of a report published in 1994 (Gebers & Peck, 1994). The report is essentially a statistical compilation of accident-risk factors (relativities) identified through a preliminary analysis of the driver record information extracted in May 2000, providing driving record information through December 1998.

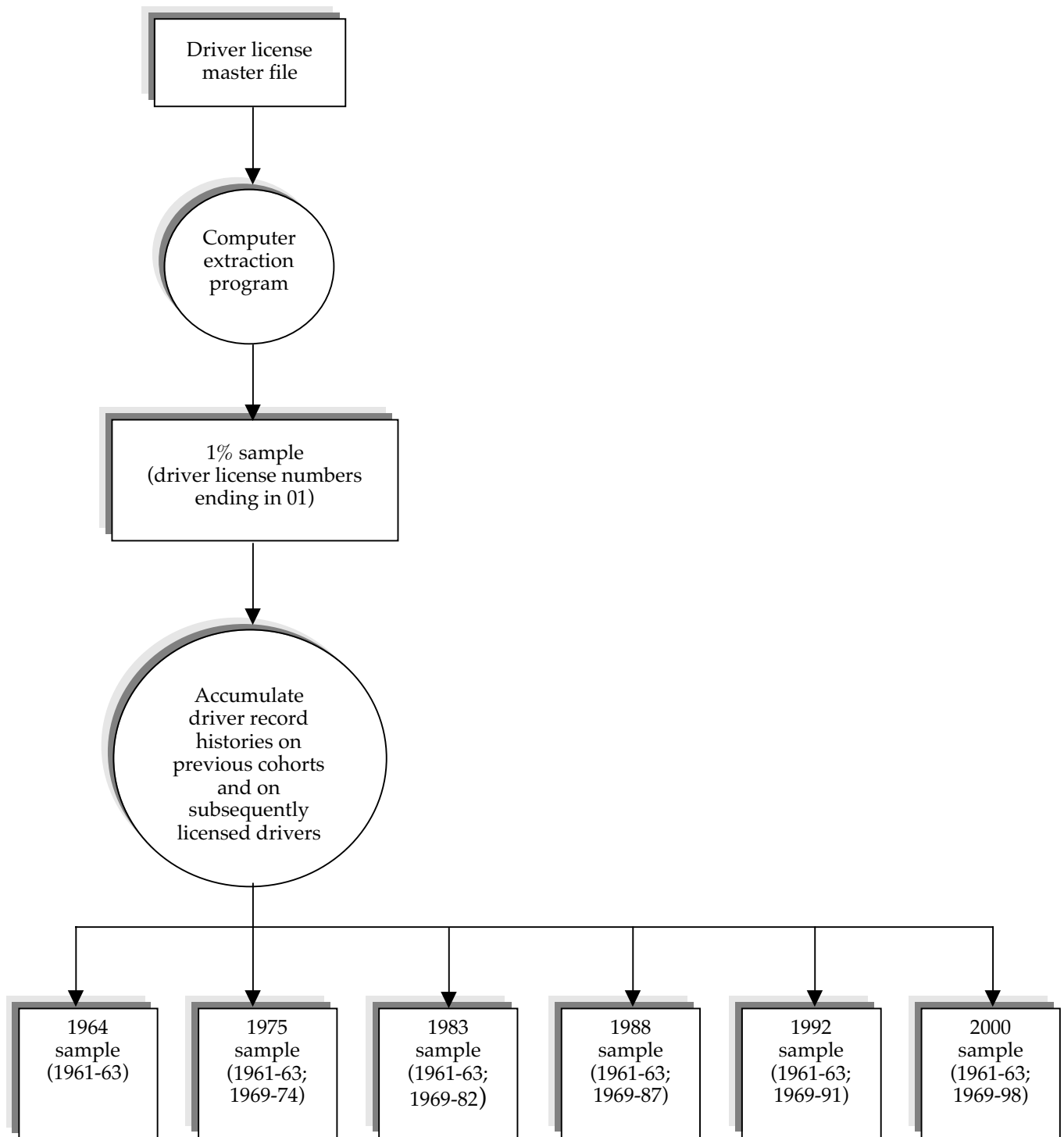
As was the case with the 1994 report, the information is presented primarily in raw tabular form with minimal interpretation. The objective is to provide report recipients and users with a comprehensive array of up-to-date accident-risk information. More formal and comprehensive analyses will continue to be produced and published as separate reports.

## METHOD

### Sample Design

The California Department of Motor Vehicles (DMV) maintains an automated file containing driving records for over 20 million California drivers. The driver license (DL) number of each record consists of a letter prefix followed by a seven-digit numerical field. License issuance is conducted in such a way that, within each prefix, the lowest numbers are issued first. When all the numbers for a given prefix have been used, a new prefix is issued. The driver record file is sequenced based on the last two digits of the DL number, from 00 through 99. Within each terminal digit, records are further sorted by letter prefix and the remainder of the DL number. Each terminal digit grouping can, therefore, be conceived of as a 1% random sample of all driver records on file. A 1% random sample of driver records, with DL numbers ending in 01, was extracted from the file on May 13, 2000.

Figure 1 summarizes the data structure of the California Driver Record Study Database, in which the sampled driver records are stored after extraction. As illustrated in the figure, a 1% random sample of the DL file has been extracted six times in the past, beginning in 1964. Driver record history data obtained from each extraction were merged, based on a matching of DL numbers, with data previously extracted for existing cohorts (previous samples). In addition, all drivers in the sample who were licensed after the previous extraction entered the database and formed the basis of future tracking.



*Note:* The time periods in parentheses represent the years for which driver record histories are available on the database. Due to a purge of data from the department's DL master file, there are no data for 1964-68.

Figure 1. Process for creating the California Driver Record Study Database.

Data for the approximately 216,000 driver records extracted in 2000 include almost everything available on the DL file—demographic data, accidents and citations by type, physical and mental (P&M) codes, suspension/revocation actions, and licensing variables such as class of license and driving restrictions. Driver record information stored on the California database covers the period 1961 through 1963 and 1969 through 1998. (Data for 1964 through 1968 were purged from the DL file before they could be extracted and, therefore, are not in the database.) The time period covered by an individual driver record is a function of when the driver was first licensed in California. To be eligible for inclusion into the sample, individuals had to possess a valid California driver license at the time of the extraction. All drivers with a “deceased” indicator on their record or whose driver license had been expired for more than 6 months were deleted from the sample.

Tables 1a and 1b display biographical and licensing characteristics of the sample.

Table 1a  
Biographical and Licensing Characteristics  
(*n* = 216,327)

Mean age	% Men	% Class 1 / A or 2 / B license	% one or more restrictions	% physical/ mental condition	% under license suspension or revocation	% motorcycle certificate	% residing in Los Angeles county	Median years of licensure in California
42.50	52.68	3.17	34.63	1.50	5.15	3.94	25.71	16.00

Table 1b  
Percentage of Drivers by Age Group  
(*n* = 216,327)

Age group	%
16-19	5.00
20-29	19.49
30-39	23.12
40-49	21.62
50-59	14.55
60-69	8.53
70-79	5.66
80+	2.04

Note: Percentages do not add to 100.00 due to rounding.

The tables indicate the following:

- 42.50 is the average age, with 24.49% being under age 30 and 7.7% being over age 70.
- 52.68% are men.
- 3.17% hold a class 1 / A or 2 / B (heavy-vehicle) commercial driver license.
- 34.63% have one or more license restrictions (e.g., must wear corrective lenses while operating a motor vehicle).
- 1.50% have a physical or mental condition on record.
- 5.15% were under a license suspension or revocation action for at least 1 month during the previous year.
- 3.94% hold a certificate allowing them to operate a motorcycle.
- 25.71% of the drivers reside in Los Angeles County.
- 16.00 years is the median length of licensure in California.

### Design and Analysis

This report presents tabulations of variables related to the assessment of traffic accident risk. (See the Appendix for a detailed description of these variables.) The information presented in the following sections range from simple descriptive statistics (e.g., percentages and means) to more complex accident prediction models produced from a statistical technique called multiple regression. Each analysis technique is defined in the relevant section below. It is assumed that the reader is familiar with the issues and terminology associated with traffic accident risk assessment. Therefore, only a minimum amount of narrative is provided. For the interested reader, a more detailed discussion can be found in Gebers (1999), Kwong, Kuan, and Peck (1976), and Peck and Kuan (1983).

It should be reiterated that it is not the objective of this report to interpret results in detail or to make recommendations. Rather, the primary purpose is to provide data on the performance of California's general driving population that may be useful in making policy decisions and formulating public safety programs, and in evaluating the effectiveness of such policies and programs.

## SECTION 1: DISTRIBUTION OF DRIVER-RECORD ENTRIES BY SEX AND AGE

It has been well established in previous studies that both sex and age are related to accident risk and citation rate (e.g., Gebers, 1999; Gebers & Peck, 2003a, b; Gebers, Romanowicz, & McKenzie, 1993; Peck & Gebers, 1992; Peck & Kuan, 1983). In these studies, men had consistently poorer per-driver incident rates than women, and young drivers had poorer per-driver incident rates than older drivers.

To illustrate the relationship between sex and accident risk, Table 2 displays percentage distributions of driver record entries by type and by sex for drivers licensed over 1-, 2-, and 3-year periods during 1996-98. Table 3 presents per-driver average number of entries by type, sex, and driver-record period. It should be noted that the sample sizes

for men and women vary because only drivers having a license throughout the requisite time period are included for each interval.

Table 2  
Percentage of Driver Record Entries by Entry Type and  
Sex of Driver for 1-, 2-, and 3-Year Driver Records

Driver-record entry Number of incidents	1998			1997-98			1996-98		
	Both sexes	Men (n = 113,941)	Women (n = 102,386)	Both sexes	Men (n = 111,036)	Women (n = 99,910)	Both sexes	Men (n = 107,718)	Women (n = 96,962)
Total accidents									
0	95.01	94.56	95.50	90.43	89.56	91.40	86.19	84.97	87.55
1	4.77	5.18	4.31	8.77	9.48	7.98	12.23	13.10	11.26
2+	0.22	0.26	0.19	0.80	0.96	0.62	1.58	1.93	1.19
Fatal/injury accidents									
0	98.65	98.52	98.81	97.30	97.04	97.59	95.96	95.58	96.37
1+	1.35	1.48	1.19	2.70	2.96	2.41	4.04	4.42	3.63
Total citations									
0	86.62	83.18	90.45	76.56	71.13	82.60	68.73	61.98	76.22
1	10.85	13.22	8.20	16.51	19.20	13.52	19.71	22.24	16.91
2	1.92	2.65	1.11	4.55	6.08	2.85	6.77	8.71	4.62
3	0.41	0.62	0.18	1.44	2.11	0.70	2.63	3.69	1.45
4+	0.20	0.33	0.06	0.94	1.48	0.33	2.16	3.38	0.80
Total citations excluding traffic violation school citation dismissals									
0	90.69	87.58	94.16	83.34	78.14	89.12	77.18	70.50	84.60
1	7.52	9.79	4.98	11.88	14.92	8.50	14.72	17.91	11.18
2	1.34	1.91	0.70	3.11	4.35	1.72	4.78	6.52	2.84
3	0.30	0.46	0.12	0.99	1.48	0.44	1.77	2.61	0.85
4+	0.15	0.26	0.04	0.68	1.11	0.22	1.55	2.46	0.53
Countable citations									
0	89.08	86.50	91.95	80.50	76.25	85.23	73.61	68.14	79.69
1	9.41	11.38	7.21	15.01	17.50	12.25	18.53	21.16	15.61
2	1.26	1.73	0.73	3.31	4.48	2.00	5.25	6.82	3.51
3+	0.25	0.39	0.11	1.18	1.77	0.52	2.61	3.88	1.19
Moving citations									
0	89.86	87.75	92.22	81.79	78.30	85.67	75.26	70.74	80.28
1	8.80	10.41	7.00	14.22	16.24	11.98	17.73	19.92	15.29
2	1.12	1.51	0.69	2.98	3.96	1.88	4.78	6.08	3.34
3+	0.22	0.33	0.09	1.01	1.50	0.47	2.23	3.26	1.09
Major citations									
0	99.07	98.53	99.68	98.25	97.22	99.40	97.40	95.87	99.10
1	0.85	1.34	0.30	1.51	2.39	0.54	2.17	3.41	0.79
2+	0.08	0.13	0.02	0.24	0.39	0.06	0.43	0.72	0.11
Negligent-operator points									
0	85.18	82.48	88.19	74.16	69.88	78.91	65.51	60.24	71.36
1	11.63	13.10	9.99	17.78	19.27	16.12	21.30	22.44	20.04
2	2.43	3.27	1.49	5.40	6.94	3.70	7.92	9.78	5.85
3	0.52	0.78	0.24	1.63	2.31	0.87	2.96	3.99	1.81
4+	0.24	0.37	0.09	1.03	1.60	0.40	2.31	3.55	0.94
Traffic violator school citation dismissals									
0	95.02	94.38	95.74	90.25	89.02	91.62	86.43	84.79	88.26
1	4.92	5.54	4.24	9.45	10.57	8.22	12.65	14.00	11.14
2+	0.06	0.08	0.03	0.30	0.41	0.16	0.92	1.21	0.60

Note. Samples include only drivers licensed during the entire 1-, 2-, and 3-year periods, respectively. Percentages may not add to 100.00 due to rounding. See the Appendix for definitions of the variables in this table.



Table 3  
Mean Number of Driver Record Entries by Sex of Driver for  
1-, 2-, and 3-Year Driver Records

Driver record entry	1998			1997-98			1996-98		
	Both sexes	Men (n = 113,941)	Women (n = 102,386)	Both sexes	Men (n = 111,036)	Women (n = 99,910)	Both sexes (n = 107,718)	Men (n = 96,962)	Women
Total accidents	0.052	0.057	0.047	0.105	0.115	0.093	0.156	0.173	0.138
Fatal/injury accidents	0.014	0.015	0.012	0.028	0.030	0.025	0.042	0.046	0.037
Total citations	0.168	0.219	0.112	0.345	0.449	0.229	0.520	0.679	0.343
Total citations excluding traffic violator school citation dismissal	0.118	0.162	0.069	0.244	0.335	0.143	0.375	0.514	0.219
Countable citations	0.128	0.161	0.090	0.257	0.326	0.180	0.383	0.488	0.267
Moving citations	0.117	0.145	0.087	0.236	0.293	0.173	0.351	0.436	0.257
Major citations	0.010	0.016	0.003	0.021	0.033	0.007	0.032	0.051	0.010
Negligent-operator points	0.191	0.236	0.141	0.383	0.476	0.279	0.572	0.714	0.415
Traffic violator school citation dismissals	0.050	0.057	0.043	0.101	0.114	0.086	0.145	0.165	0.124

*Note.* Samples include only drivers licensed during the entire 1-, 2-, and 3-year periods, respectively.

The data in Tables 2 and 3 indicate that most drivers have very good records, that extremely deviant records are quite rare, and that, as mentioned, men have poorer records than do women.

The above relationships are further illustrated in Figures 2 and 3. These figures indicate that during the cumulative 3-year period of 1996-98:

- 86.19% of the drivers were accident-free.
- 68.73% of the drivers were citation-free.
- 97.40% of the drivers did not have a major citation (e.g., driving under the influence of alcohol or drugs and reckless driving).
- Men drivers had 1.25 times (17.3/13.8) as many total accident involvements, 1.97 times (67.9/34.4) as many total citations, and 5.1 (5.1/1.0) times as many major citations than did women drivers.

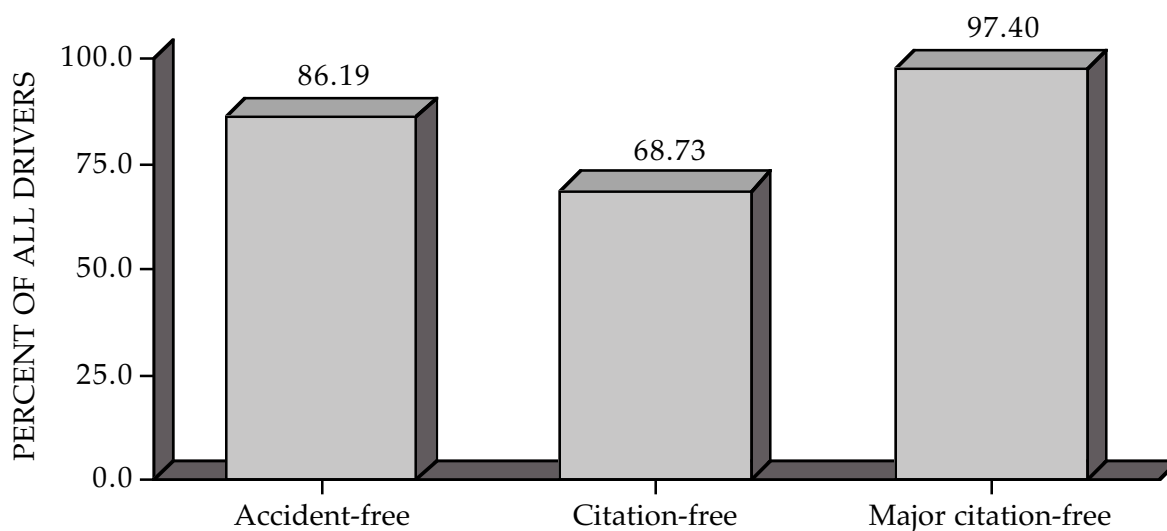


Figure 2. Percentage of all drivers who were incident-free during 1996-98.

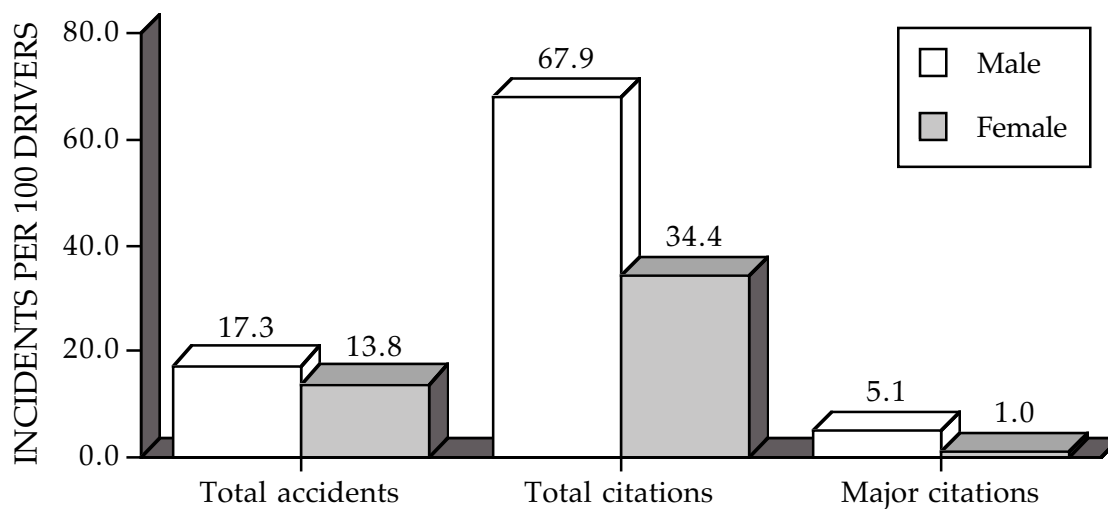


Figure 3. Total accidents, total citations, and major citations per 100 drivers by sex during 1996-98.

For both sexes, driver age is also related to accidents and citations. The annual average accident involvement and citation rates per 100 drivers for each age and sex group are displayed in Table 4.

Table 4

Annual Total Accidents and Total Citations Per 100 Licensed Drivers by Age Group and Sex

Age group	Total accidents			Total citations		
	Both sexes	Men (n = 107,718)	Women (n = 96,962)	Both sexes	Men (n = 107,718)	Women (n = 96,962)
16-19	8.48	9.19	7.73	36.31	49.25	22.54
20-24	6.85	7.43	6.18	30.93	41.01	19.34
25-29	5.49	6.00	4.88	23.72	30.29	15.95
30-34	5.14	5.46	4.77	20.24	25.31	14.31
35-39	5.08	5.50	4.58	17.20	21.65	12.08
40-44	4.92	5.41	4.38	14.56	18.45	10.25
45-49	4.60	5.25	3.89	11.89	15.30	8.23
50-54	4.17	4.80	3.48	10.35	13.44	6.97
55-59	4.04	4.79	3.21	8.54	11.45	5.33
60-64	3.79	4.35	3.18	6.74	9.11	4.13
65-69	3.77	4.35	3.15	5.32	7.42	3.11
70-74	4.10	4.84	3.40	4.02	5.80	2.34
75-79	4.26	4.95	3.64	2.79	4.20	1.52
80-84	4.71	5.70	3.74	2.86	4.19	1.56
85 and older	5.16	5.92	4.31	2.43	3.51	1.23
All ages	5.18	5.73	4.56	17.33	22.63	11.45

Note. Averages represent accidents and citations occurring during 1996-98.

Table 5 shows relative involvement (risk) indices for accident involvements and citations by age and sex. The index for each age/sex group was calculated by dividing the average (mean) accident or citation rate for the group by the grand mean for all drivers. For example, if a certain age/sex group had an accident rate of 10 per 100 drivers, and all licensed drivers had an accident rate of 5 per 100 drivers, the relative involvement index for the group would be 2 (10/5). This would indicate that the age/sex group was involved in twice as many accidents as would be expected relative to all drivers. The indices can be made sex-specific by dividing each age/sex group's index by the "all ages" index for that sex. For example, the accident involvement index for males aged 16-19 compared to males overall is 1.59 (1.77/1.11).

Because essentially equivalent information is given by group rates and relative indices, Figures 4 and 5 present both types of information, on separate ordinates, for accident and citations, respectively. In each figure, the left-hand ordinate represents accident involvement or citation rate, and the right-hand ordinate represents relative accident involvement or citation index. These data are from Tables 4 and 5.

Table 5

Relative Annual Total Accident and Total Citation Rates by Age Group and Sex

Age group	Total accidents			Total citations		
	Both sexes	Men (n = 107,718)	Women (n = 96,962)	Both sexes	Men (n = 107,718)	Women (n = 96,962)
16-19	1.64	1.77	1.49	2.10	2.84	1.30
20-24	1.32	1.43	1.19	1.78	2.37	1.12
25-29	1.06	1.16	0.94	1.37	1.75	0.92
30-34	0.99	1.05	0.92	1.17	1.46	0.83
35-39	0.98	1.06	0.88	0.99	1.25	0.70
40-44	0.95	1.04	0.85	0.84	1.06	0.59
45-49	0.89	1.01	0.75	0.69	0.88	0.47
50-54	0.81	0.93	0.67	0.60	0.78	0.40
55-59	0.78	0.92	0.62	0.49	0.66	0.31
60-64	0.73	0.84	0.61	0.39	0.53	0.24
65-69	0.73	0.84	0.61	0.31	0.43	0.18
70-74	0.79	0.93	0.66	0.23	0.33	0.14
75-79	0.82	0.96	0.70	0.16	0.24	0.09
80-84	0.91	1.10	0.72	0.17	0.24	0.09
85 and older	1.00	1.14	0.83	0.14	0.20	0.07
All ages	1.00	1.11	0.88	1.00	1.31	0.66

Note. Indices derived from accidents and citations occurring during 1996-98.

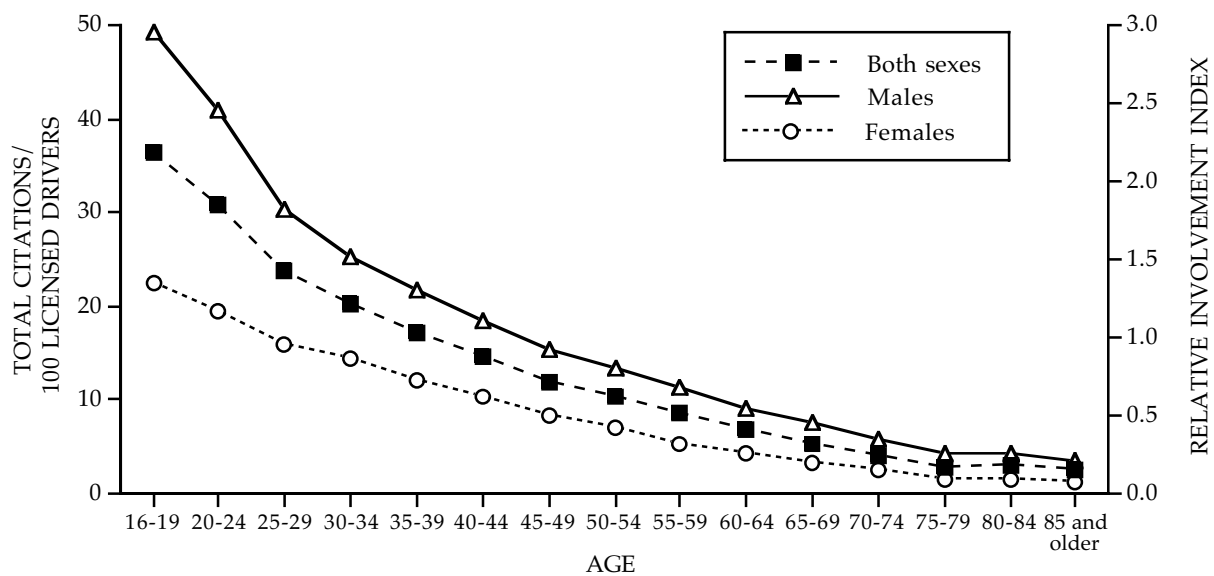


Figure 4. Annual total citation rate and relative involvement index by age and sex.

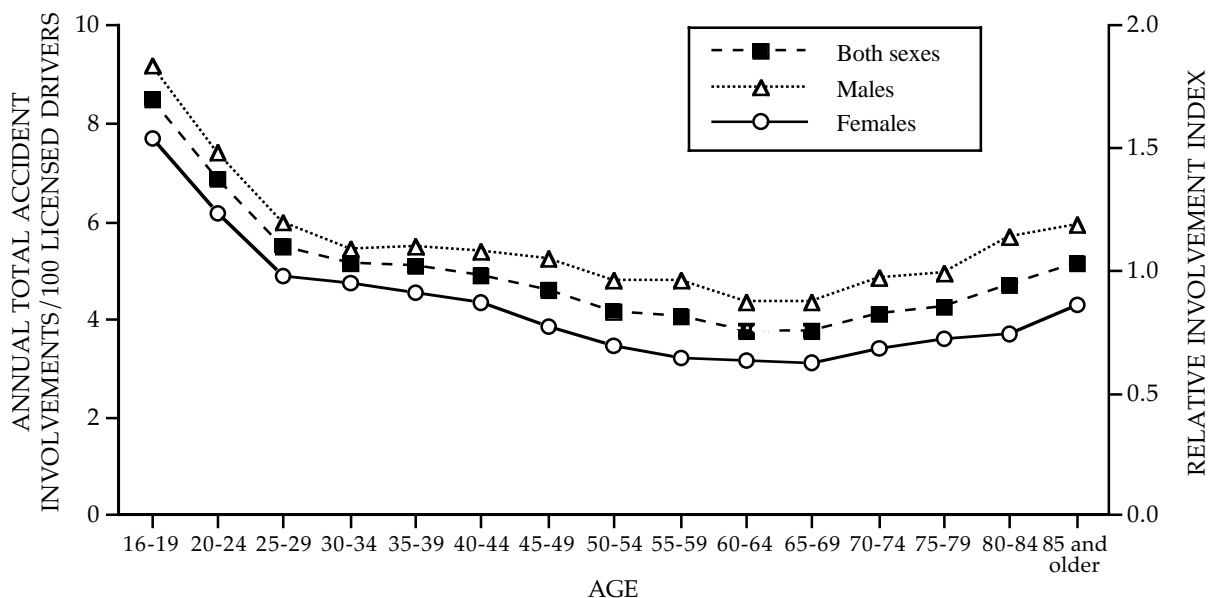


Figure 5. Annual total accident involvement rate and relative involvement index by age and sex.

Tables 4 and 5 and Figures 4 and 5 indicate the following:

- Teen drivers have the highest accident-involvement and citation rates.
- As drivers age, there is a downward trend in the citation rate.
- As drivers age, their accident-involvement rate decreases through about age 69 and then rises somewhat.

In the above age and sex comparisons on accident risk, the rates are not adjusted for mileage. Everything else being equal, higher mileage affords more opportunity for accidents and violations to occur, and men tend to accumulate more mileage than do women. The effect of mileage is covered in Janke, Masten, McKenzie, Gebers, & Kelsey (2003) and, therefore, is not discussed in detail here.

#### Conclusions

- Most drivers have very good records.
- Extremely deviant records are quite rare.
- Driver age is related to accidents and citations for both sexes.
- Teen drivers have the highest accident-involvement and citation rates. As drivers age, their accident-involvement rate decreases through about age 69 and then increases somewhat. As drivers age, there is a monotonic downward trend in the citation rate.
- Men have a substantially higher incidence of traffic accidents and traffic citations than do women, but much of this gender difference is attributable to the higher driving mileage of men drivers.

## SECTION 2: NONCONCURRENT SUBSEQUENT ACCIDENTS BY PRIOR DRIVER RECORD ENTRIES

### Analytical Procedures

In this section, tabulations of 5-, 6-, 8-, 9-, and 12-year nonconcurrent accidents by driver record incidents are presented. A nonconcurrent relationship is one in which a criterion variable (e.g., subsequent total accidents) can be predicted to some degree by a variable that has been measured during a prior period of time (e.g., prior citations). The analyses of nonconcurrent relationships presented in this section are designed to assist in determining relative risk of future accident involvement on the basis of past driver record performance.

Tables 6 through 45 present a common way of expressing risk in terms of the risk of a no-prior incident group. To predict accidents in a subsequent period from citations in a prior period, e.g., three citations in the prior 2 years, the average number of subsequent accident involvements for a particular group of drivers is divided by the average number of subsequent accidents for drivers having no prior citations in the same 2-year period. By using this “times-as-many” relationship, the subsequent accident rate for a group of drivers having a specific number of prior citations is indexed to the accident rate for the zero-prior citation group. The higher the times-as-many index, the greater the risk of a prior-incident group relative to the risk of the group with no prior incidents, which by definition has a times-as-many index of 1.0. For the example above, a quotient of 3.1 would indicate that the group with three prior citations had 3.1 times-as-many subsequent accidents as had drivers with no prior citations.

Tables 6 through 45 each present a Pearson correlation coefficient. This coefficient is an index of how closely, and in what direction, two variables are related, and can vary from -1 to +1. The Pearson correlation is measured at the individual level in contrast to the times-as-many index, which is measured at the group level. A correlation of -1 or +1 would indicate perfect association, meaning that every individual’s score on one variable could be perfectly predicted from their score on the other variable. A correlation of 0 would indicate the complete absence of association. In “real world” prediction, perfect correlations (i.e., -1 or +1) are rarely, if ever, found. The sign of the coefficient indicates the direction of the relationship, with a negative sign indicating an inverse relationship in which one variable tends to increase as the other variable decreases.

Tables 46 through 57 illustrate three-variable relationships. In each table, the frequency of two prior driver record variables (e.g., citations and accidents) is cross-tabulated with the percentage and mean distributions of subsequent accident involvements. These tabulations allow an assessment of relative accident risk as a function of a combination of two prior driver record variables. For example, one could assess how the future accident risk of a group of drivers with one prior citation and no prior accidents compares to the future accident risk of a group of drivers with one prior citation and two prior accidents.

The following results represent driver record trends apparent in these data. The general statements apply to the 5-, 8-, and 9-year data as a whole, whereas specific numerical examples are derived from selected 6- and 12-year distributions.

### Results

Two-Variable Relative Risk Relationships. The data presented in Tables 6 through 45 clearly illustrate the fact that prior driver record is predictive of subsequent accident record. In every case, drivers with prior driver record entries represent a greater risk of subsequent accident involvement relative to drivers with clean records.

Tables 14, 15, and 16: Rate of Subsequent Total Accidents in 1996-98 by the Number of Total Accidents, Total Citations, and Responsible Accidents in the Prior 3 Years (1993-95). This trend is displayed in Tables 14, 15, and 16 and graphically illustrated in Figures 6, 7, and 8. These tables and figures show subsequent accident rate by prior total accidents, prior total citations, and prior responsible accidents, respectively. Tables 14, 15, and 16 and Figures 6, 7, and 8 indicate the following:

- The group of drivers with three or more accidents in the first 3 years (1993-95) had 3.26 times-as-many accidents in the next 3 years (1996-98) as did the group with no prior accident involvements.
- The group of drivers with six or more citations in the first 3 years (1993-95) had 2.44 times-as-many accidents in the next 3 years (1996-98) as did the group with no prior citations.
- The group of drivers with two or more responsible accidents in the first 3 years (1993-95) had 2.77 times-as-many accidents in the next 3 years (1996-98) as did the group with no responsible accidents.

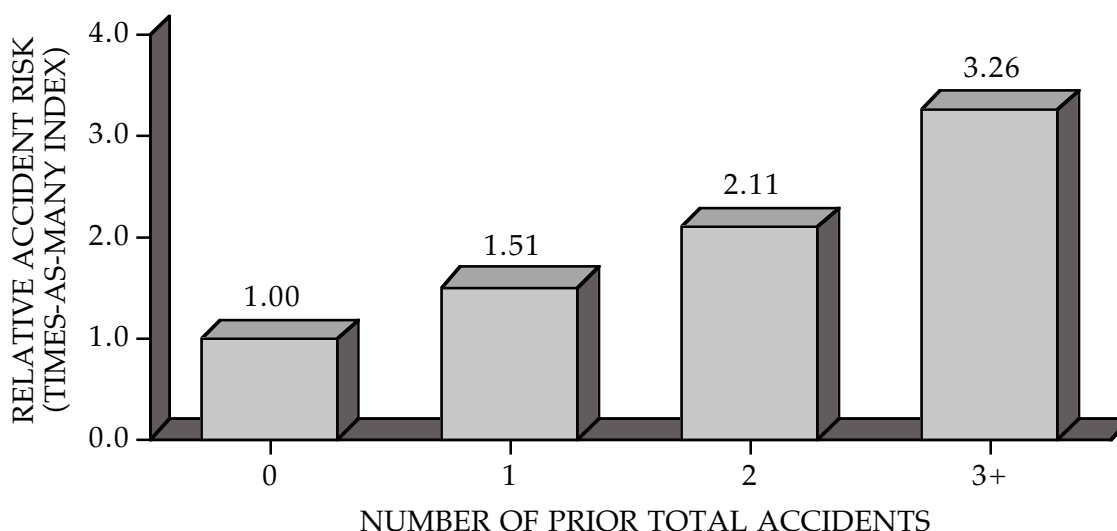


Figure 6. Relative subsequent accident risk (1996-98) by number of total accidents in the prior 3 years (1993-95).

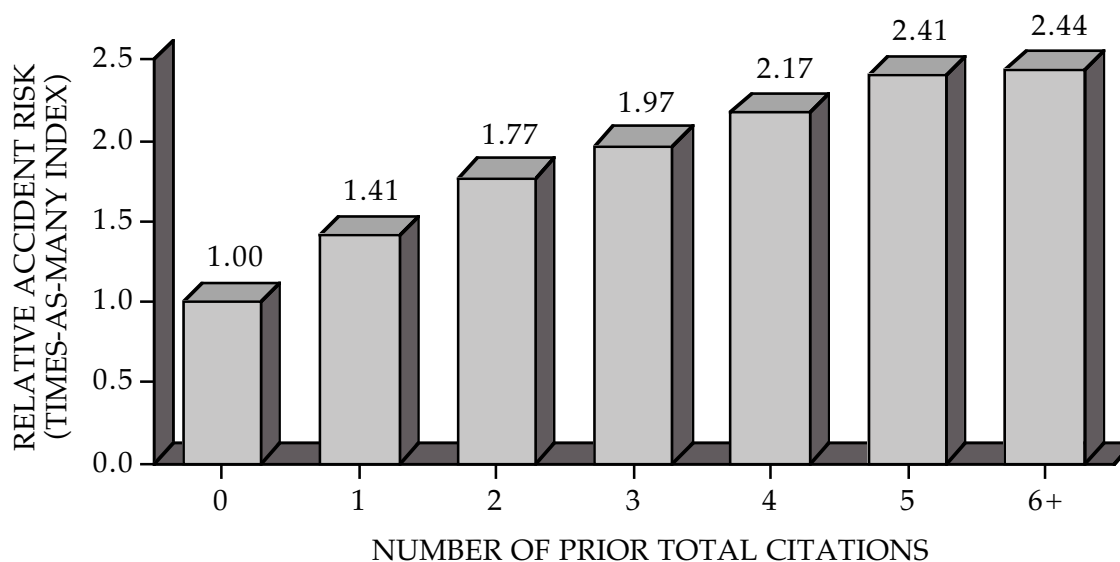


Figure 7. Relative subsequent accident risk (1996-98) by number of total citations in the prior 3 years (1993-95).

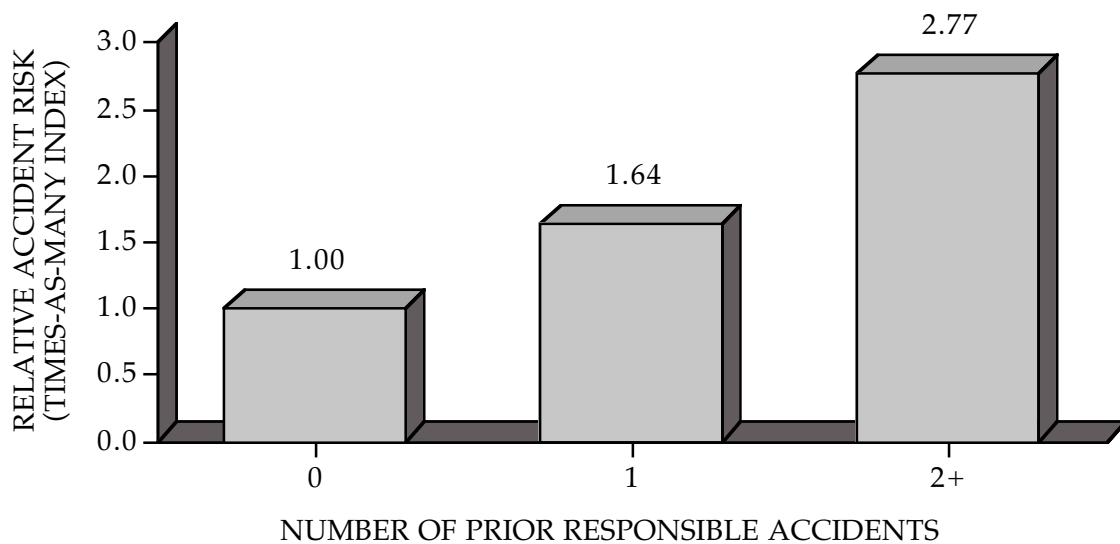


Figure 8. Relative subsequent accident risk (1996-98) by number of responsible accidents in the prior 3 years (1993-95).



Although large differences in accident involvement rates exist between driver groups with differing numbers of accident and citation types, a substantial percentage of drivers, even in the worst groups, remain accident-free. For example, Tables 14, 15, and 16 indicate the following:

- 66.37% of the drivers with three or more accidents during 1993-95 were accident-free during the next 3 years (1996-98).
- 75.34% of the drivers with six or more citations during 1993-95 were accident-free during the next 3 years (1996-98).
- 68.63% of the drivers with two or more responsible accidents during 1993-95 were accident-free during the next 3 years (1996-98).

As mentioned previously, each table contains a Pearson correlation coefficient measuring the strength of the relationship between prior record and subsequent accident involvement (for different variables and time periods) at an individual, rather than at a group, level. The correlations from Tables 14, 15, and 16 are computed as the following:

- .074 for the relationship between prior 3-year total accident involvement and subsequent 3-year total accident involvement.
- .096 for the relationship between prior 3-year total citations and subsequent 3-year total accident involvement.
- .051 for the relationship between prior 3-year responsible accidents and subsequent 3-year total accident involvement.

The positive direction of each coefficient indicates that increases in prior accidents and citations are associated with increases in subsequent accident involvements, with prior citations generally functioning as a better predictor of accidents than prior accident involvement. However, the fact that total citations accounts for only .92% ( $.096 \times .096$ ) of the variance would indicate that knowing an individual driver had accumulated a certain number of citations during a specific time period would not permit a very accurate estimate of the same driver's future accident involvement.

In interpreting these correlations, it is important to keep in mind the distinction between individual and group prediction when evaluating the effectiveness of an accident-prediction system. Many researchers (e.g., Gebers, 1999; Gebers & Peck, 2003a, b; Peck & Kuan, 1983) believe that although accurate individual prediction is always a relevant and desirable goal, it is not always a critical or attainable goal. Peck and Kuan (1983) note that the actuarial sciences inevitably involve very large numbers of risk entities, and the actuary must establish a premium structure and funding pool that is sufficient to offset the net dollar amount of claims made over a fixed period of time. For example, if one has established that persons who smoke have a three-fold greater-than-average probability of dying than do non-smokers, all members of the smoking group

might be charged a higher life insurance premium—presumably one that is proportionate to the greater risk of that group’s early mortality. In doing so, it should be recognized that many individuals in the smoking group will not get lung cancer and will actually live longer than average and end up paying more than their “fare share.” Conversely, some proportion of non-smokers will contract lung cancer and die early and pay less than their “fare share.” A large number of misassessments are a consequence of the fact that smoking still only predicts a small percentage of the variance in the death rate of the individuals comprising any population.

In these tables, there is a marked trend toward increased accident involvement as a function of a driver’s prior accident and citation frequency; however, as noted above, the majority of drivers are accident-free at all prior incident levels. This implies that any graduated premium structure based on prior driver record would necessarily penalize a substantial number of drivers who should not be involved in an accident during the period of time for which the premium is charged. However, when examining the data on a group basis in terms of the number of accidents per 100 drivers in each category, it is evident that drivers with poor records have many more accidents than do drivers who are incident-free. Therefore, from an actuarial standpoint, these data would clearly support charging bad-record drivers higher premiums because the expected number of accident claims filed by these drivers as a group is much higher than that for good-record drivers as a group.

It should also be noted that the results in the tables indicate that the policy of dismissing traffic citations in lieu of attending traffic violator schools (California Vehicle Code Section 42005) distorts DMV’s database and reduces the ability to use driver record information to predict, or calibrate, the future accident expectancies of drivers. For example, the correlation of .096 from Table 15 drops to .078 (Table 17) when TVS dismissals are excluded from the citation count. This 19% drop in the magnitude of the correlation corroborates prior DMV studies (Gebers, Tashima, & Marsh, 1987; Gebers, Peck, Janke, & Hagge, 1993; Peck & Gebers, 1991). These authors found that, since citation points are valid indicators of future accident risk, any understatement of an offender’s citation record results in an underestimate of the offender’s accident risk.

Table 20: Rate of Subsequent Total Accidents in 1996-98 by Number of Negligent-Operator (Neg-Op) Points in the Prior 3 Years (1993-95). The relationship between subsequent accidents and prior citations provides solid support for DMV’s neg-op point system, which triggers license control actions based on the driver’s neg-op point count. The interested reader is referred to Peck and Healey (1995) for an overview of findings and program improvements related to California’s Negligent Operator Treatment Program Evaluation System between 1976 and 1995.

Table 20 presents the accident times-as-many factors based on 6-year data. Because neg-op points are based primarily on convictions of moving violations (comprising the majority of traffic citations), the relationship between accidents and points displayed in the tables is similar to that between accidents and total citations.

The times-as-many indices in Table 20 support the following conclusions:

- The group of drivers accumulating three points in 3 years (1993-95) had 2.18 times-as-many accidents as did the group of clean drivers.
- The group of neg-ops accumulating six or more points in 3 years (1993-95) had 2.52 times-as-many accidents as did the group of clean drivers.

Inspection of comparable correlation coefficients with those for traffic citations indicates that neg-op points are slightly better predictors of future accident risk. For example, the coefficients for 6-year data are .096 versus .103 when using citations and neg-op points, respectively, as predictors (Tables 15 and 20).

Tables 38, 39, and 44: Rate of Total Accidents in 1990-95 by Number of Total Accidents, Total Citations, and Neg-Op Points in the Prior 6 Years (1984-89). One method of increasing the reliability of prior driving incidents as a measure of driving performance is to lengthen the time over which the events are accumulated. Tables 38, 39, and 44 present the relationship between subsequent 6-year accident frequencies by prior 6-year total accidents, total citations, and neg-op points, respectively. Figure 9 compares the correlations for 6-year data with those for 12-year data. In each case, the correlation coefficient for the longer time period is much greater. For example, the correlation for 12-year accidents by neg-op points is .164, while that for the 6-year data is .103. Although this increase in correlation is substantial, it still does not represent a strong relationship for predicting the accident involvement rates for individual drivers.

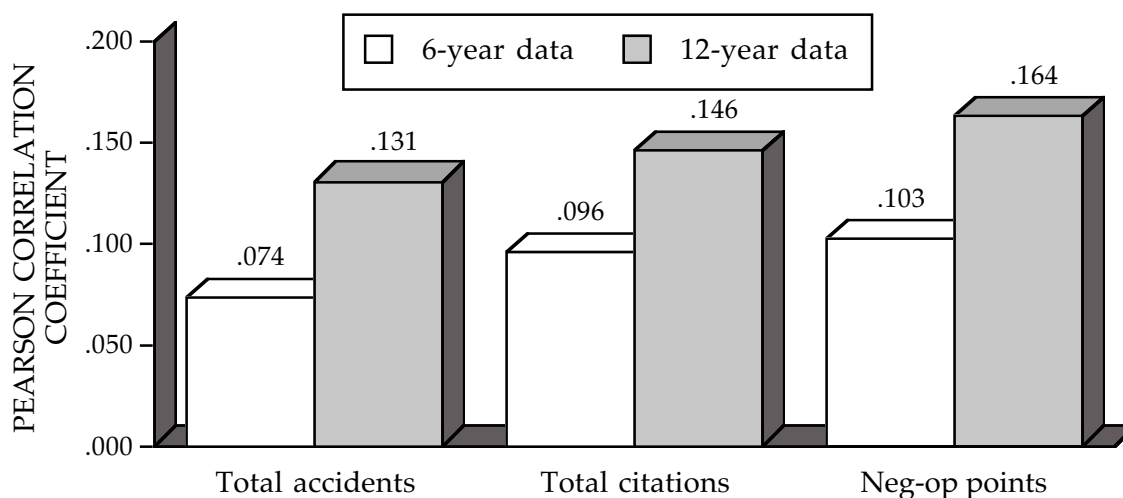


Figure 9. Relationship between subsequent total accident involvements and prior driving incidents for 6- and 12-year data.

Three-Variable Relative Risk Relationships. Tables 46 through 57 present 6-, 8-, and 12-year “three-way” relative risk tables. These tables allow an assessment of accident risk across levels of various citation types, as well as within each citation level at various levels of prior accident involvement.

Tables 46 and 47: Rate of Subsequent Total Accidents and Responsible Accidents in 1996-98 by Number of Total Citations and Total Accidents in the Prior 3 Years (1993-95). Table 46 displays subsequent total accident involvements by prior total citations and total accident involvements. Table 47 displays subsequent responsible (culpable) accident involvements by prior total citations and total accident involvements. These data indicate that:

- Drivers with four or more total citations in the prior 3 years have 2.29 times-as-many accidents in the subsequent 3 years as drivers with no prior citations (0.289/0.126).
- Drivers with four or more total citations in the prior 3 years have 3.58 times-as-many responsible accidents as drivers with no prior citations (0.111/0.031).

The tables also indicate that, within each citation level, drivers with prior accident entries are at a greater risk of future accident involvement. For example,

- Drivers with four or more prior citations and two or more prior accident involvements have 1.43 times-as-many subsequent total accidents in the next 3 years as do drivers with four or more prior citations and no prior accidents (0.379/0.265).
- Drivers with four or more prior citations and two or more prior accident involvements have 1.29 times-as-many subsequent responsible accidents in the next 3 years as do drivers with four or more prior citations and no prior accidents (0.130/0.101).

### Conclusions

- Accident risk increases as a function of the number of accidents and citations on the driver's prior record. Of the two, prior citations is slightly superior as an indicator of subsequent accident risk.
- Subsequent accident risk can be more accurately predicted from a combination of prior accident and citation information than from either alone.
- Use of a longer period for counting prior incidents increases the accuracy of accident-risk prediction.
- The total number of accidents on the driver's prior record is a better indicator of subsequent accident risk than are responsible accidents.
- The inclusion of TVS dismissals in the prior citation counts results in increased accuracy of accident-risk assessment.
- Neg-op points are slightly better predictors of future accident risk than are prior accidents and prior citations. This relationship provides solid support for the department's neg-op point system, which triggers license control actions based on a driver's point count.

Table 6

Rate of Subsequent Total Accidents in 1997-98 by  
Number of Total Accidents in the Prior 3 Years (1994-96)

Prior total accidents (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	164,952	0.095	1.00	91.21
1	22,801	0.142	1.49	87.35
2	2,717	0.191	2.01	83.47
3+	335	0.322	3.39	76.12

*Note.* Pearson correlation coefficient between prior and subsequent total accidents is .062 ( $p < .0001$ ).

Table 7

Rate of Subsequent Total Accidents in 1997-98 by  
Number of Total Citations in the Prior 3 Years (1994-96)

Prior total Citations (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	129,490	0.085	1.00	92.08
1	38,261	0.122	1.44	88.85
2	13,317	0.153	1.80	86.31
3	5,194	0.168	1.98	84.98
4	2,290	0.186	2.19	83.45
5+	2,253	0.217	2.55	81.58

*Note.* Pearson correlation coefficient between prior total citations and subsequent total accidents is .082 ( $p < .0001$ ).

Table 8

Rate of Subsequent Total Accidents in 1997-98 by  
Number of Responsible Accidents in the Prior 3 Years (1994-96)

Prior responsible accidents (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	183,251	0.100	1.00	90.78
1	7,187	0.155	1.55	86.73
2+	367	0.229	2.29	80.93

*Note.* Pearson correlation coefficient between prior responsible accidents and subsequent total accidents is .035 ( $p < .0001$ ).

Table 9

Rate of Subsequent Total Accidents in 1997-98 by Number of Total Citations (Excluding TVS Dismissals) in the Prior 3 Years (1994-96)

Prior total citations (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	144,268	0.090	1.00	91.63
1	29,700	0.127	1.41	88.49
2	9,651	0.151	1.68	86.51
3	3,727	0.162	1.80	85.67
4	1,678	0.180	2.00	83.91
5+	1,781	0.202	2.24	82.65

Note. Pearson correlation coefficient between prior total citations and subsequent total accidents is .066 ( $p < .0001$ ).

Table 10

Rate of Subsequent Total Accidents in 1997-98 by Number of Countable Citations in the Prior 3 Years (1994-96)

Prior countable citations (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	139,898	0.088	1.00	91.89
1	35,474	0.130	1.48	88.16
2	10,096	0.160	1.82	85.76
3	3,466	0.196	2.23	82.66
4	1,200	0.192	2.18	83.08
5+	671	0.250	2.85	80.03

Note. Pearson correlation coefficient between prior countable citations and subsequent total accidents is .082 ( $p < .0001$ ).

Table 11

Rate of Subsequent Total Accidents in 1997-98 by Number of Moving Citations in the Prior 3 Years (1994-96)

Prior moving citations (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	143,192	0.088	1.00	91.88
1	33,997	0.133	1.51	87.90
2	9,123	0.166	1.89	85.27
3	3,005	0.206	2.34	81.83
4	985	0.205	2.33	81.93
5+	503	0.266	3.03	78.73

Note. Pearson correlation coefficient between prior moving citations and subsequent total accidents is .085 ( $p < .0001$ ).

Table 12

Rate of Subsequent Total Accidents in 1997-98 by Number of  
Negligent-Operator (Neg-Op) Points in the Prior 3 Years (1994-96)

Prior neg-op points (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	124,726	0.083	1.00	92.27
1	40,462	0.123	1.48	88.79
2	15,250	0.150	1.80	86.62
3	5,697	0.181	2.18	84.01
4	2,594	0.193	2.32	83.96
5+	2,076	0.222	2.68	81.84

Note. Pearson correlation coefficient between prior neg-op points and subsequent total accidents is .088 ( $p < .0001$ ).

Table 13

Rate of Subsequent Total Accidents in 1997-98 by  
Number of Major (2-Point) Citations in the Prior 3 Years (1994-96)

Prior major citations (1994-96)	Number of drivers	Mean subsequent accident rate (1997-98)	Times-as-many subsequent accidents (1997-98)	% subsequent accident-free drivers (1997-98)
0	185,587	0.102	1.00	90.64
1	4,222	0.117	1.15	89.51
2	712	0.117	1.15	89.61
3+	284	0.137	1.35	88.38

Note. Pearson correlation coefficient between prior major citations and subsequent total accidents is .007 ( $p < .0001$ ).

Table 14

Rate of Subsequent Total Accidents in 1996-98 by  
Number of Total Accidents in the Prior 3 Years (1993-95)

Prior total accidents (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	159,937	0.140	1.00	87.42
1	21,990	0.211	1.51	81.96
2	2,576	0.296	2.11	76.67
3+	333	0.456	3.26	66.37

Note. Pearson correlation coefficient between prior and subsequent total accidents is .074 ( $p < .0001$ ).

Table 15

Rate of Subsequent Total Accidents in 1996-98 by  
Number of Total Citations in the Prior 3 Years (1993-95)

Prior total citations (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	124,136	0.126	1.00	88.60
1	37,526	0.178	1.41	84.31
2	13,446	0.223	1.77	80.67
3	5,283	0.248	1.97	79.25
4	2,293	0.274	2.17	77.28
5	1,057	0.304	2.41	74.36
6+	1,095	0.307	2.44	75.34

Note. Pearson correlation coefficient between prior total citations and subsequent total accidents is .096 ( $p < .0001$ ).

Table 16

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Responsible Accidents in the Prior 3 Years (1993-95)

Prior total responsible accidents (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	177,617	0.147	1.00	86.86
1	6,897	0.241	1.64	80.34
2+	322	0.407	2.77	68.63

Note. Pearson correlation coefficient between prior total responsible accidents and subsequent total accidents is .051 ( $p < .0001$ ).

Table 17

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Citations (Excluding TVS Dismissals) in the Prior 3 Years (1993-95)

Prior total citations (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	138,496	0.134	1.00	87.99
1	29,338	0.184	1.37	83.88
2	9,720	0.225	1.68	80.77
3	3,892	0.239	1.78	79.70
4	1,680	0.266	1.99	77.92
5	845	0.295	2.20	75.27
6+	865	0.279	2.08	77.46

Note: Pearson correlation coefficient between prior total citations and subsequent total accidents is .078 ( $p < .0001$ ).



Table 18

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Countable Citations in the Prior 3 Years (1993-95)

Prior total countable citations (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	134,342	0.130	1.00	88.32
1	34,837	0.188	1.45	83.46
2	10,349	0.263	2.02	79.82
3	3,406	0.282	2.17	76.86
4	1,201	0.270	2.08	76.94
5	409	0.345	2.65	73.59
6+	292	0.346	2.66	71.92

Note: Pearson correlation coefficient between prior total countable citations and subsequent total accidents is .094 ( $p < .0001$ ).

Table 19

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Moving Citations in the Prior 3 Years (1993-95)

Prior total moving citations (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	137,796	0.130	1.00	88.29
1	33,272	0.192	1.48	83.16
2	9,364	0.247	1.90	79.07
3	2,908	0.298	2.29	75.65
4	978	0.280	2.15	76.07
5	311	0.357	2.75	71.38
6+	207	0.386	2.97	69.57

Note: Pearson correlation coefficient between prior total moving citations and subsequent total accidents is .098 ( $p < .0001$ ).

Table 20

Rate of Subsequent Total Accidents in 1996-98 by  
Number of Neg-Op Points in the Prior 3 Years (1993-95)

Prior neg-op points (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	119,951	0.123	1.00	88.84
1	39,252	0.179	1.46	84.20
2	15,280	0.219	1.78	81.41
3	5,662	0.268	2.18	77.52
4	2,560	0.274	2.23	76.84
5	1,026	0.306	2.49	76.80
6+	1,105	0.310	2.52	75.84

Note: Pearson correlation coefficient between prior neg-op points and subsequent total accidents is .103 ( $p < .0001$ ).

Table 21

Rate of Subsequent Total Accidents in 1996-98 by  
Number of Major (2-Point) Citations in the Prior 3 Years (1993-95)

Prior major citations (1993-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	179,484	0.151	1.00	86.63
1	4,247	0.168	1.11	85.24
2	758	0.172	1.14	85.49
3+	347	0.193	1.28	83.29

Note. Pearson correlation coefficient between prior major citations and subsequent total accidents is .008 ( $p = .0008$ ).

Table 22

Rate of Subsequent Total Accidents in 1994-98 by  
Number of Total Accidents in the Prior 3 Years (1991-93)

Prior total accidents (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	147,245	0.228	1.00	80.74
1	19,914	0.348	1.53	72.51
2	2,322	0.488	2.14	64.99
3+	313	0.665	2.91	54.95

Note. Pearson correlation coefficient between prior and subsequent total accidents is .096 ( $p < .0001$ ).

Table 23

Rate of Subsequent Total Accidents in 1994-98 by  
Number of Total Citations in the Prior 3 Years (1991-93)

Prior total citations (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	111,452	0.207	1.00	82.31
1	36,220	0.289	1.40	76.26
2	12,881	0.349	1.69	72.28
3	5,139	0.406	1.96	68.79
4	2,182	0.407	1.97	68.65
5	977	0.413	2.00	68.47
6+	943	0.445	2.15	67.66

Note. Pearson correlation coefficient between prior total citations and subsequent total accidents is .107 ( $p < .0001$ ).

Table 24

Rate of Subsequent Total Accidents in 1994-98 by Number of  
Total Responsible Accidents in the Prior 3 Years (1991-93)

Prior total responsible accidents (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	163,256	0.241	1.00	79.86
1	6,242	0.379	1.57	71.23
2+	296	0.595	2.47	60.47

Note. Pearson correlation coefficient between prior total responsible and subsequent total accidents is .055 ( $p < .0001$ ).

Table 25

Rate of Subsequent Total Accidents in 1994-98 by Number of  
Total Citations (Excluding TVS Dismissals) in the Prior 3 Years (1991-93)

Prior total citations (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	125,664	0.220	1.00	81.35
1	28,219	0.294	1.34	76.15
2	9,272	0.360	1.64	71.66
3	3,626	0.380	1.73	70.57
4	1,573	0.383	1.74	69.74
5	723	0.433	1.97	67.50
6+	717	0.397	1.81	70.85

Note. Pearson correlation coefficient between prior total citations and subsequent total accidents is .085 ( $p < .0001$ ).

Table 26

Rate of Subsequent Total Accidents in 1994-98 by Number of  
Total Countable Citations in the Prior 3 Years (1991-93)

Prior total countable citations (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	119,396	0.211	1.00	81.98
1	34,297	0.301	1.43	75.46
2	10,585	0.372	1.76	70.90
3	3,515	0.420	1.99	67.80
4	1,251	0.430	2.04	67.07
5	468	0.415	1.97	67.74
6+	282	0.443	2.10	69.50

Note. Pearson correlation coefficient between prior total countable citations and subsequent total accidents is .105 ( $p < .0001$ ).

Table 27

Rate of Subsequent Total Accidents in 1994-98 by Number of  
Total Moving Citations in the Prior 3 Years (1991-93)

Prior total moving citations (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	122,967	0.212	1.00	81.92
1	32,720	0.308	1.45	74.96
2	9,582	0.383	1.81	70.31
3	2,968	0.437	2.06	66.75
4	1,015	0.438	2.07	66.70
5	351	0.453	2.14	65.53
6+	191	0.524	2.47	63.87

Note. Pearson correlation coefficient between prior total moving citations and subsequent total accidents is .110 ( $p < .0001$ ).

Table 28

Rate of Subsequent Total Accidents in 1994-98 by Number of  
Major (2-Point) Citations in the Prior 3 Years (1991-93)

Prior Major citations (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	164,375	0.245	1.00	79.58
1	4,155	0.268	1.09	77.93
2	838	0.307	1.25	74.82
3+	426	0.272	1.11	77.46

Note. Pearson correlation coefficient between prior major citations and subsequent total accidents is .009 ( $p = .0003$ ).

Table 29

Rate of Subsequent Total Accidents in 1994-98 by Number of  
Neg-Op Points in the Prior 3 Years (1991-93)

Prior neg-op points (1991-93)	Number of drivers	Mean subsequent accident rate (1994-98)	Times-as-many subsequent accidents (1994-98)	% subsequent accident-free drivers (1994-98)
0	107,047	0.200	1.00	82.78
1	37,183	0.287	1.44	76.33
2	15,074	0.357	1.78	72.10
3	5,677	0.408	2.04	68.47
4	2,561	0.421	2.10	68.18
5	1,052	0.443	2.21	65.97
6+	1,200	0.444	2.22	67.83

Note. Pearson correlation coefficient between prior neg-op points and subsequent total accidents is .117 ( $p < .0001$ ).

Table 30

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Accidents in the Prior 6 Years (1990-95)

Prior total accidents (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	123,262	0.126	1.00	88.54
1	31,411	0.188	1.49	83.59
2	6,294	0.254	2.02	78.76
3	1,275	0.330	2.62	73.73
4+	340	0.500	3.97	62.65

Note. Pearson correlation coefficient between prior total accidents and subsequent total accidents is .100 ( $p < .0001$ ).

Table 31

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Citations in the Prior 6 Years (1990-95)

Prior total citations (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	80,828	0.110	1.00	89.93
1	38,406	0.150	1.36	86.45
2	19,387	0.182	1.65	84.08
3	10,146	0.204	1.85	82.15
4	5,665	0.225	2.05	80.72
5	3,157	0.235	2.14	80.14
6	1,911	0.253	2.30	79.07
7	1,138	0.267	2.43	77.42
8+	1,944	0.297	2.70	76.08

Note. Pearson correlation coefficient between prior total citations and subsequent total accidents is .104 ( $p < .0001$ ).

Table 32

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Responsible Accidents in the Prior 6 Years (1990-95)

Prior total responsible accidents (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	150,660	0.139	1.00	87.52
1	10,947	0.220	1.58	81.56
2	878	0.317	2.28	74.83
3+	97	0.464	3.34	70.10

Note. Pearson correlation coefficient between prior total responsible accidents and subsequent total accidents is .063 ( $p < .0001$ ).

Table 33

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Citations (Excluding TVS Dismissals) in the Prior 6 Years (1990-95)

Prior total citations (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	99,019	0.121	1.00	88.98
1	32,666	0.158	1.31	85.89
2	14,140	0.190	1.57	83.53
3	7,182	0.206	1.70	82.14
4	3,855	0.220	1.82	81.19
5	2,213	0.248	2.05	78.99
6	1,289	0.244	2.02	80.14
7	828	0.256	2.12	78.74
8+	1,390	0.282	2.33	76.83

*Note.* Pearson correlation coefficient between prior total citations and subsequent total accidents is .085 ( $p < .0001$ ).

Table 34

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Countable Citations in the Prior 6 Years (1990-95)

Prior total countable citations (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	89,958	0.114	1.00	89.64
1	38,761	0.160	1.40	85.73
2	17,644	0.189	1.66	83.44
3	8,132	0.218	1.91	81.15
4	3,909	0.244	2.14	79.46
5	2,074	0.266	2.33	77.24
6	998	0.245	2.15	79.96
7	542	0.347	3.04	73.06
8+	564	0.351	3.08	72.70

*Note.* Pearson correlation coefficient between prior total countable citations and subsequent total accidents is .103 ( $p < .0001$ ).

Table 35

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Total Moving Citations in the Prior 6 Years (1990-95)

Prior total moving citations (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	93,803	0.114	1.00	89.59
1	38,210	0.163	1.43	85.47
2	16,592	0.194	1.70	83.07
3	7,218	0.231	2.03	80.15
4	3,435	0.246	2.16	79.27
5	1,688	0.284	2.49	76.13
6	847	0.256	2.25	78.87
7	393	0.379	3.32	70.23
8+	396	0.381	3.34	71.46

*Note.* Pearson correlation coefficient between prior total moving citations and subsequent total accidents is .107 ( $p < .0001$ ).

Table 36

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Neg-Op Points in the Prior 6 Years (1990-95)

Prior neg-op points (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	74,005	0.103	1.00	90.51
1	39,805	0.148	1.44	86.59
2	22,090	0.176	1.71	84.47
3	11,536	0.210	2.04	82.05
4	6,276	0.229	2.22	80.61
5	3,560	0.256	2.48	77.92
6	2,156	0.258	2.51	78.90
7	1,159	0.278	2.70	77.31
8+	1,995	0.311	3.02	75.04

*Note.* Pearson correlation coefficient between prior neg-op points and subsequent total accidents is .116 ( $p < .0001$ ).

Table 37

Rate of Subsequent Total Accidents in 1996-98 by Number of  
Major (2-Point) Citations in the Prior 6 Years (1990-95)

Prior major citations (1990-95)	Number of drivers	Mean subsequent accident rate (1996-98)	Times-as-many subsequent accidents (1996-98)	% subsequent accident-free drivers (1996-98)
0	154,090	0.144	1.00	87.14
1	6,016	0.171	1.19	85.12
2	1,496	0.155	1.08	85.96
3+	980	0.185	1.28	84.49

Note. Pearson correlation coefficient between prior major citations and subsequent total accidents is .012 ( $p < .0001$ ).

Table 38

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Total Accidents in the Prior 6 Years (1984-89)

Prior total accidents (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	87,237	0.243	1.00	79.68
1	24,257	0.346	1.42	72.80
2	5,180	0.476	1.96	65.46
3	1,026	0.687	2.83	56.34
4+	325	0.871	3.58	51.08

Note. Pearson correlation coefficient between prior and subsequent total accidents is .131 ( $p < .0001$ ).

Table 39

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Total Citations in the Prior 6 Years (1984-89)

Prior total citations (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	56,104	0.208	1.00	82.26
1	27,189	0.280	1.35	77.04
2	14,095	0.347	1.67	72.45
3	7,909	0.378	1.82	70.73
4	4,587	0.406	1.95	69.44
5	2,852	0.456	2.19	65.60
6	1,668	0.472	2.27	65.65
7	1,152	0.519	2.50	63.37
8+	2,469	0.565	2.71	61.56

Note. Pearson correlation coefficient between prior total citations and subsequent total accidents is .146 ( $p < .0001$ ).



Table 40

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Total Responsible Accidents in the Prior 6 Years (1984-89)

Prior total responsible accidents (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	108,843	0.269	1.00	78.06
1	8,353	0.405	1.51	69.80
2	733	0.543	2.02	63.03
3+	96	0.750	2.79	52.08

*Note.* Pearson correlation coefficient between prior total responsible accidents and subsequent total accidents is .074 ( $p < .0001$ ).

Table 41

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Total Citations (Excluding TVS Dismissals) in the Prior 6 Years (1984-89)

Prior total citations (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	64,700	0.226	1.00	81.03
1	25,276	0.291	1.29	76.25
2	12,074	0.354	1.57	72.12
3	6,214	0.384	1.70	70.66
4	3,589	0.407	1.80	69.69
5	2,114	0.454	2.01	66.79
6	1,306	0.466	2.06	65.62
7	811	0.498	2.20	64.00
8+	1,941	0.539	2.38	62.75

*Note.* Pearson correlation coefficient between prior total citations and subsequent total accidents is .124 ( $p < .0001$ ).

Table 42

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Total Countable Citations in the Prior 6 Years (1984-89)

Prior total countable citations (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	60,585	0.212	1.00	81.99
1	27,961	0.292	1.38	76.18
2	13,606	0.360	1.70	71.51
3	7,074	0.398	1.88	69.73
4	3,802	0.436	2.06	66.99
5	2,064	0.491	2.32	64.97
6	1,173	0.519	2.45	64.11
7	744	0.536	2.53	61.29
8+	1,016	0.664	3.13	56.40

*Note.* Pearson correlation coefficient between prior total countable citations and subsequent total accidents is .149 ( $p < .0001$ ).

Table 43

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Total Moving Citations in the Prior 6 Years (1984-89)

Prior total moving citations (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	62,896	0.213	1.00	81.91
1	27,706	0.295	1.38	75.96
2	12,965	0.368	1.73	70.96
3	6,576	0.410	1.92	69.04
4	3,449	0.449	2.11	66.14
5	1,892	0.510	2.39	64.06
6	1,011	0.518	2.43	63.80
7	664	0.601	2.82	57.08
8+	866	0.682	3.20	56.00

*Note.* Pearson correlation coefficient between prior total moving citations and subsequent total accidents is .153 ( $p < .0001$ ).

Table 44

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Neg-Op Points in the Prior 6 Years (1984-89)

Prior neg-op points (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	49,706	0.194	1.00	83.23
1	28,272	0.271	1.40	77.56
2	16,280	0.333	1.72	73.34
3	9,315	0.375	1.94	70.78
4	5,452	0.421	2.17	68.01
5	3,392	0.458	2.36	66.39
6	1,978	0.504	2.60	63.85
7	1,274	0.506	2.61	65.07
8+	2,356	0.591	3.05	60.27

*Note.* Pearson correlation coefficient between prior neg-op points and subsequent total accidents is .164 ( $p < .0001$ ).

Table 45

Rate of Subsequent Total Accidents in 1990-95 by Number of  
Major (2-Point) Citations during the Prior 6 Years (1984-89)

Prior major citations (1984-89)	Number of drivers	Mean subsequent accident rate (1990-95)	Times-as-many subsequent accidents (1990-95)	% subsequent accident-free drivers (1990-95)
0	111,745	0.278	1.00	77.54
1	4,799	0.339	1.22	73.14
2	1,084	0.311	1.12	75.92
3+	397	0.252	0.91	80.86

*Note.* Pearson correlation coefficient between prior major citations and subsequent total accidents is .014 ( $p < .0001$ ).

Table 46

Rate of Subsequent Total Accidents in 1996-98 by Number of Total Citations and Total Accidents in the Prior 3 Years (1993-95)

Prior total citations (1993-95)	Prior total accidents (1993-95)	Number of drivers	% of total drivers involved in subsequent accidents (1996-98)			Mean subsequent total accidents (1996-98)
			0	1	2+	
0	0	111,443	89.10	9.94	0.96	0.120
	1	11,484	84.63	13.51	1.86	0.176
	2+	1,209	80.40	15.14	4.46	0.256
						$\bar{X} = 0.126$
1	0	31,044	85.12	13.28	1.60	0.166
	1	5,755	81.34	15.93	2.73	0.220
	2+	727	73.18	21.46	5.36	0.345
						$\bar{X} = 0.178$
2	0	10,445	81.88	15.78	2.34	0.208
	1	2,542	77.07	19.59	3.34	0.268
	2+	459	73.20	22.22	4.58	0.318
						$\bar{X} = 0.223$
3	0	3,918	80.42	16.51	3.07	0.232
	1	1,136	77.46	19.19	3.35	0.266
	2+	229	68.12	23.58	8.30	0.432
						$\bar{X} = 0.248$
4+	0	3,087	77.68	18.89	3.43	0.265
	1	1,073	73.16	21.44	5.40	0.336
	2+	285	70.18	23.86	5.96	0.379
						$\bar{X} = 0.289$

*Note.* Sample is limited to drivers licensed for the entire 6-year (1993-98) period. Percentages may not add to 100.00 due to rounding.

Table 47

Rate of Subsequent Responsible Accidents in 1996-98 by Number of Total Citations and Total Accidents in the Prior 3 Years (1993-95)

Prior total citations (1993-95)	Prior total accidents (1993-95)	Number of drivers	% of total drivers involved in subsequent responsible accidents (1996-98)			Mean subsequent responsible accidents (1996-98)
			0	1	2+	
0	0	111,443	97.13	2.77	0.10	0.030
	1	11,484	96.09	3.74	0.17	0.041
	2+	1,209	94.46	5.05	0.49	0.061
						$\bar{X} = 0.031$
1	0	31,044	95.57	4.21	0.22	0.047
	1	5,755	94.40	5.14	0.46	0.062
	2+	727	91.47	7.70	0.83	0.095
						$\bar{X} = 0.050$
2	0	10,445	94.21	5.51	0.28	0.061
	1	2,542	92.21	7.36	0.43	0.083
	2+	459	88.02	11.55	0.43	0.126
						$\bar{X} = 0.067$
3	0	3,918	93.06	6.30	0.64	0.077
	1	1,136	91.29	8.10	0.61	0.093
	2+	229	87.77	9.61	2.62	0.149
						$\bar{X} = 0.083$
4+	0	3,087	90.38	9.14	0.48	0.101
	1	1,073	88.16	10.34	1.50	0.135
	2+	285	89.47	8.07	2.46	0.130
						$\bar{X} = 0.111$

*Note.* Sample is limited to drivers licensed for the entire 6-year (1993-98) period. Percentages may not add to 100.00 due to rounding.

Table 48

Rate of Subsequent Total Accidents in 1996-98 by Number of Major Citations and Total Accidents in the Prior 3 Years (1993-95)

Prior major citations (1993-95)	Prior total accidents (1993-95)	Number of drivers	% of total drivers involved in subsequent accidents (1996-98)			Mean subsequent total accidents (1996-98)
			0	1	2+	
0	0	156,034	87.45	11.29	1.26	0.140
	1	20,755	81.90	15.57	2.53	0.212
	2+	2,695	75.29	19.48	5.23	0.318
						$\bar{X} = 0.151$
1	0	3,104	86.47	11.86	1.67	0.154
	1	972	82.51	15.23	2.26	0.198
	2+	171	78.36	18.13	3.51	0.257
						$\bar{X} = 0.168$
2+	0	799	85.11	12.64	2.25	0.174
	1	263	85.17	13.31	1.52	0.167
	2+	43	76.74	16.28	6.98	0.326
						$\bar{X} = 0.178$

*Note.* Sample is limited to drivers licensed for the entire 6-year (1993-98) period. Percentages may not add to 100.00 due to rounding.

Table 49

Rate of Subsequent Total Accidents in 1996-98 by Number of Total Countable Citations and Total Accidents in the Prior 3 Years (1993-95)

Prior total countable citations (1993-95)	Prior total accidents (1993-95)	Number of drivers	% of total drivers involved in subsequent accidents (1996-98)			Mean subsequent total accidents (1996-98)
			0	1	2+	
0	0	119,951	88.84	10.16	1.00	0.123
	1	12,993	84.36	13.67	1.97	0.180
	2+	1,398	80.11	15.45	4.44	0.259
						$\bar{X} = 0.130$
1	0	28,447	84.43	13.83	1.74	0.175
	1	5,619	80.07	17.05	2.88	0.233
	2+	771	72.37	22.83	4.80	0.345
						$\bar{X} = 0.188$
2	0	7,818	81.20	16.17	2.63	0.218
	1	2,115	76.36	20.14	3.50	0.277
	2+	416	71.63	21.63	6.74	0.365
						$\bar{X} = 0.236$
3	0	2,417	78.40	17.75	3.85	0.262
	1	803	75.47	20.30	4.23	0.299
	2+	186	62.90	29.57	7.53	0.468
						$\bar{X} = 0.282$
4+	0	1,304	75.84	20.63	3.53	0.285
	1	460	74.57	20.00	5.43	0.322
	2+	138	74.64	18.84	6.52	0.341
						$\bar{X} = 0.298$

*Note.* Sample is limited to drivers licensed over the entire 6-year (1993-98) period. Percentages may not add to 100.00 due to rounding.

Table 50

Rate of Subsequent Total Accidents in 1994-98 by Number of Total Citations and Total Accidents in the Prior 3 Years (1991-93)

Prior total citations (1991-93)	Prior total accidents (1991-93)	Number of drivers	% of total drivers involved in subsequent accidents (1994-98)			Mean subsequent total accidents (1994-98)
			0	1	2+	
0	0	100,305	83.08	14.60	2.32	0.196
	1	10,132	75.95	19.71	4.34	0.293
	2+	1,015	69.16	22.36	8.48	0.428
						$\bar{X} = 0.207$
1	0	30,157	77.52	18.77	3.71	0.269
	1	5,347	71.03	22.50	6.47	0.372
	2+	716	62.29	27.79	9.92	0.517
						$\bar{X} = 0.289$
2	0	10,134	73.92	21.14	4.94	0.322
	1	2,337	67.18	24.69	8.13	0.432
	2+	410	60.98	26.59	12.43	0.552
						$\bar{X} = 0.349$
3	0	3,847	70.34	22.80	6.86	0.380
	1	1,081	66.05	25.25	8.70	0.446
	2+	211	54.50	30.81	14.69	0.683
						$\bar{X} = 0.406$
4+	0	2,802	70.45	22.95	6.60	0.377
	1	1,017	65.19	24.98	9.83	0.477
	2+	283	59.36	28.62	12.02	0.590
						$\bar{X} = 0.417$

*Note.* Sample is limited to drivers licensed during the entire 8-year (1991-98) period. Percentages may not add to 100.00 due to rounding.



Table 51

Rate of Subsequent Responsible Accidents in 1994-98 by Number of  
Total Citations and Total Accidents in the Prior 3 Years (1991-93)

Prior total citations (1991-93)	Prior total accidents (1991-93)	Number of drivers	% of total drivers involved in subsequent responsible accidents (1994-98)			Mean subsequent responsible accidents (1994-98)
			0	1	2+	
0	0	100,305	95.55	4.23	0.22	0.047
	1	10,132	93.57	6.00	0.43	0.069
	2+	1,015	91.53	7.68	8.47	0.094
						$\bar{X} = 0.049$
1	0	30,157	93.52	6.04	0.44	0.070
	1	5,347	90.67	8.55	0.78	0.102
	2+	716	87.99	10.20	1.81	0.148
						$\bar{X} = 0.076$
2	0	10,134	91.11	8.32	0.57	0.095
	1	2,337	89.30	9.46	1.24	0.122
	2+	410	84.88	12.44	2.68	0.185
						$\bar{X} = 0.103$
3	0	3,847	89.06	9.77	1.17	0.122
	1	1,081	86.22	12.58	1.20	0.150
	2+	211	79.62	16.11	4.27	0.270
						$\bar{X} = 0.134$
4+	0	2,802	87.79	10.89	1.32	0.137
	1	1,017	85.25	12.78	1.97	0.170
	2+	283	78.09	19.43	2.48	0.244
						$\bar{X} = 0.152$

*Note:* Sample is limited to drivers licensed over the entire 8-year (1991-98) period. Percentages may not add to 100.00 due to rounding.

Table 52

Rate of Subsequent Total Accidents in 1994-98 by Number of Total Major Citations and Total Accidents in the Prior 3 Years (1991-93)

Prior total major citations (1991-93)	Prior total accidents (1991-93)	Number of drivers	% of total drivers involved in subsequent accidents (1994-98)			Mean subsequent total accidents (1994-98)
			0	1	2+	
0	0	143,242	80.78	16.25	2.97	0.227
	1	18,740	72.48	21.57	5.95	0.350
	2+	2,393	63.39	25.99	10.62	0.516
						$\bar{X} = 0.245$
1	0	3,122	80.20	16.37	3.43	0.240
	1	875	72.23	22.97	4.80	0.334
	2+	158	64.56	27.85	7.59	0.456
						$\bar{X} = 0.268$
2+	0	881	75.94	20.32	3.74	0.286
	1	299	75.59	20.40	4.01	0.291
	2+	84	73.81	17.86	8.33	0.405
						$\bar{X} = 0.295$

Note: Sample is limited to drivers licensed over the entire 8-year (1991-98) period. Percentages may not add to 100.00 due to rounding.

Table 53

Rate of Subsequent Total Accidents in 1994-98 by Number of Total Countable Citations and Total Accidents in the Prior 3 Years (1991-93)

Prior total countable citations (1991-93)	Prior total accidents (1991-93)	Number of drivers	% of total drivers involved in subsequent accidents (1994-98)			Mean subsequent total accidents (1994-98)
			0	1	2+	
0	0	107,047	82.78	14.84	2.38	0.200
	1	11,199	75.79	19.71	4.50	0.298
	2+	1,150	68.09	22.78	9.13	0.450
						$\bar{X} = 0.211$
1	0	28,200	76.96	19.12	3.92	0.278
	1	5,335	69.56	23.56	6.88	0.391
	2+	762	61.15	28.48	10.37	0.525
						$\bar{X} = 0.301$
2	0	8,126	72.51	21.78	5.71	0.345
	1	2,066	66.36	25.36	8.28	0.442
	2+	393	61.58	25.45	12.97	0.565
						$\bar{X} = 0.372$
3	0	2,534	68.82	24.07	7.11	0.399
	1	794	68.14	22.54	9.32	0.430
	2+	187	52.41	35.29	12.30	0.674
						$\bar{X} = 0.420$
4+	0	1,338	69.58	23.62	6.80	0.388
	1	520	63.27	26.35	10.38	0.504
	2+	143	64.34	25.17	10.49	0.532
						$\bar{X} = 0.428$

*Note.* Sample is limited to drivers licensed over the entire 8-year (1991-98) period. Percentages may not add to 100.00 due to rounding.

Table 54

Rate of Subsequent Total Accidents in 1990-95 by Number of Total Citations and Total Accidents in the Prior 6 Years (1984-89)

Prior total citations (1984-89)	Prior total accidents (1984-89)	Number of drivers	% of total drivers involved in subsequent accidents (1990-95)			Mean subsequent total accidents (1990-95)
			0	1	2+	
0	0	46,357	83.50	14.35	2.15	0.190
	1	8,394	77.64	18.43	3.93	0.273
	2+	1,353	68.66	22.69	8.65	0.428
						$\bar{X} = 0.208$
1	0	19,937	78.62	17.97	3.41	0.255
	1	5,921	73.87	20.84	5.29	0.329
	2+	1,331	67.47	24.72	7.81	0.436
						$\bar{X} = 0.280$
2	0	9,398	73.83	21.27	4.90	0.321
	1	3,706	71.13	22.48	6.39	0.370
	2+	991	64.28	25.13	10.59	0.504
						$\bar{X} = 0.347$
3	0	4,902	73.38	20.99	5.63	0.334
	1	2,224	68.79	24.15	7.06	0.401
	2+	783	59.64	26.56	13.80	0.589
						$\bar{X} = 0.378$
4	0	2,654	72.95	20.54	6.51	0.351
	1	1,357	66.18	25.57	8.25	0.447
	2+	576	60.94	27.95	11.11	0.559
						$\bar{X} = 0.405$
5	0	1,549	67.53	25.18	7.29	0.413
	1	916	64.74	26.64	8.62	0.469
	2+	387	59.95	26.87	13.18	0.594
						$\bar{X} = 0.456$
6	0	863	68.25	23.52	8.23	0.418
	1	529	65.97	24.57	9.46	0.459
	2+	276	56.88	25.00	31.88	0.667
						$\bar{X} = 0.472$
7	0	550	64.45	25.45	10.10	0.487
	1	401	63.59	26.43	9.98	0.506
	2+	201	57.21	28.36	14.43	0.632
						$\bar{X} = 0.519$
8+	0	1,027	64.65	26.10	9.25	0.489
	1	809	62.67	26.70	10.63	0.522
	2+	633	55.13	27.17	17.70	0.743
						$\bar{X} = 0.565$

Note: Sample is limited to drivers licensed during the entire 12-year (1984-95) period. Percentages may not add to 100.00 due to rounding.

Table 55

Rate of Subsequent Responsible Accidents in 1990-95 by Number of  
Total Citations and Total Accidents in the Prior 6 Years (1984-89)

Prior total citations (1984-89)	Prior total accidents (1984-89)	Number of drivers	% of total drivers involved in subsequent responsible accidents (1990-95)			Mean subsequent responsible accidents (1990-95)
			0	1	2+	
0	0	46,357	96.18	3.66	0.16	0.040
	1	8,394	94.71	4.97	0.32	0.057
	2+	1,353	92.90	6.36	0.74	0.079
						$\bar{X} = 0.043$
1	0	19,937	94.75	4.99	0.26	0.055
	1	5,921	93.30	6.13	0.57	0.074
	2+	1,331	91.81	7.21	0.98	0.093
						$\bar{X} = 0.061$
2	0	9,398	92.51	6.93	0.56	0.081
	1	3,706	92.04	7.26	0.70	0.087
	2+	991	88.90	10.19	0.91	0.121
						$\bar{X} = 0.085$
3	0	4,902	91.90	7.63	0.47	0.086
	1	2,224	90.38	8.86	0.76	0.105
	2+	783	85.19	13.54	1.27	0.164
						$\bar{X} = 0.099$
4	0	2,654	91.15	8.03	0.82	0.099
	1	1,357	88.73	9.87	1.40	0.129
	2+	576	85.59	12.85	1.56	0.163
						$\bar{X} = 0.116$
5	0	1,549	89.15	10.20	0.65	0.115
	1	916	86.46	12.88	0.66	0.145
	2+	387	85.53	11.11	3.36	0.184
						$\bar{X} = 0.134$
6	0	863	90.96	8.23	0.81	0.099
	1	529	86.01	12.48	1.51	0.159
	2+	276	80.43	16.30	64.13	0.232
						$\bar{X} = 0.140$
7	0	550	86.55	10.91	2.54	0.164
	1	401	86.03	11.47	2.50	0.170
	2+	201	79.6	16.92	3.48	0.244
						$\bar{X} = 0.180$
8+	0	1,027	83.25	14.31	2.44	0.200
	1	809	83.93	13.47	2.60	0.187
	2+	633	78.83	16.90	4.27	0.269
						$\bar{X} = 0.213$

Note: Sample is limited to drivers licensed during the entire 12-year (1984-95) period. Percentages may not add to 100.00 due to rounding.

Table 56

Rate of Subsequent Total Accidents in 1990-95 by Number of Total Major Citations and Total Accidents in the Prior 6 Years (1984-89)

Prior total major citations (1984-89)	Prior total accidents (1984-89)	Number of drivers	% of total drivers involved in subsequent accidents (1990-95)			Mean subsequent Total accidents (1990-95)
			0	1	2+	
0	0	83,827	79.80	16.88	3.32	0.242
	1	22,258	72.85	21.34	5.81	0.347
	2+	5,660	62.61	25.81	11.58	0.536
						$\bar{X} = 0.278$
1	0	2,707	75.77	20.10	4.13	0.292
	1	1,481	71.30	23.23	5.47	0.353
	2+	611	65.96	23.24	10.80	0.517
						$\bar{X} = 0.339$
2	0	518	78.38	17.76	3.86	0.263
	1	390	74.62	18.97	6.41	0.336
	2+	176	71.59	20.45	7.96	0.398
						$\bar{X} = 0.311$
3+	0	185	87.03	10.27	2.70	0.178
	1	128	76.56	20.31	3.13	0.273
	2+	84	73.81	20.24	5.95	0.381
						$\bar{X} = 0.252$

Note: Sample is limited to drivers licensed for the entire 12-year (1984-95) period. Percentages may not add to 100.00 due to rounding.

Table 57

Rate of Subsequent Total Accidents in 1990-95 by Number of Total Countable Citations and Total Accidents in the Prior 6-Years (1984-89)

Prior total countable citations (1984-89)	Prior total accidents (1984-89)	Number of drivers	% of total drivers involved in subsequent accidents (1990-95)			Mean subsequent total accidents (1990-95)
			0	1	2+	
0	0	49,706	83.23	14.53	2.24	0.194
	1	9,335	77.50	18.47	4.03	0.276
	2+	1,544	69.11	22.41	8.48	0.422
						$\bar{X} = 0.212$
1	0	20,084	77.76	18.55	3.69	0.266
	1	6,359	73.39	21.20	5.41	0.334
	2+	1,518	66.86	24.37	8.77	0.454
						$\bar{X} = 0.292$
2	0	8,809	73.41	21.52	5.07	0.327
	1	3,682	69.72	23.68	6.60	0.388
	2+	1,115	62.33	26.91	10.76	0.530
						$\bar{X} = 0.360$
3	0	4,229	72.52	21.26	6.22	0.350
	1	2,048	67.97	24.56	7.47	0.419
	2+	797	59.47	25.97	14.56	0.596
						$\bar{X} = 0.398$
4	0	2,062	70.22	23.13	6.65	0.382
	1	1,200	64.42	26.33	9.25	0.468
	2+	540	60.37	27.96	11.67	0.574
						$\bar{X} = 0.436$
5	0	1,101	67.85	23.16	8.99	0.4351
	1	629	63.75	25.76	10.49	0.504
	2+	334	57.78	26.05	16.17	0.653
						$\bar{X} = 0.491$
6	0	515	63.11	27.77	9.12	0.485
	1	419	66.59	23.15	10.26	0.482
	2+	239	61.92	21.34	40.58	0.657
						$\bar{X} = 0.519$
7	0	325	66.15	24.62	9.23	0.471
	1	250	60.00	28.00	12.00	0.552
	2+	169	53.85	32.54	13.61	0.639
						$\bar{X} = 0.536$
8+	0	406	62.07	26.85	11.08	0.554
	1	335	58.21	30.45	11.34	0.588
	2+	275	45.82	32.36	21.82	0.92
						$\bar{X} = 0.664$

Note: Sample is limited to drivers licensed during the entire 12-year (1984-95) period. Percentages may not add to 100.00 due to rounding.

### SECTION 3: CONCURRENT ACCIDENTS BY DRIVER RECORD ENTRIES

#### Analytical Procedures

Tables 58 through 61 present the rate of total accidents by number of citations of various types during a concurrent 6-year period. Concurrent data are measured over the same time period.

Concurrent relationships between predictors and criterion measures share some features that limit their use for certain purposes. One serious limitation is that the events may not be independent. For example, the occurrence of an accident can trigger the issuance of a traffic citation, thereby inflating the true association between the two events (Peck, McBride, & Coppin, 1971). Additionally, because the events can occur at any particular time during the interval, the structure of the relationship is not necessarily in a direction compatible with true prediction of the criterion. That is, for example, when predicting accident occurrence from citation experience, one must be aware that some of the accidents would have occurred before some of the violations leading to conviction. The correlations in the tables therefore do not represent truly predictive (nonrecursive) relationships in which the predictor measures are always antecedent to the criterion measures. A third feature to remember is that (everything else being equal) concurrent relationships are inherently stronger than predictive relationships because the variables being correlated are impacted by the same time-dependent exogenous factors. In the case of accidents and citations, for example, both are directly related to the number of miles driven during the same time interval. The existence of this relationship introduces an additional (noncausal) association between the two types of events.

#### Results

As was the case for the nonconcurrent data, the concurrent tables indicate that drivers with successive driver record entries are at a greater risk of accident involvement. For example, Table 58 and Figure 10 show the times-as-many factor for 6-year (1993-98) concurrent total accidents by total citations. These data indicate the following:

- Drivers with five citations have approximately 2.94 times-as-many accidents during a concurrent 6-year period than do drivers with no citations.
- Drivers with 8 or more citations have 4.05 times-as-many accidents during a concurrent 6-year period than do drivers with no citations.

As was also the case with the nonconcurrent data, a sizable number of drivers in the worst citation groups remain accident-free. For example, Table 58 indicates the following:

- 56.89% of the drivers with five total citations remain accident-free during a concurrent 6-year period.
- 47.81% of the drivers with 8 or more total citations remain accident-free during a concurrent 6-year period.



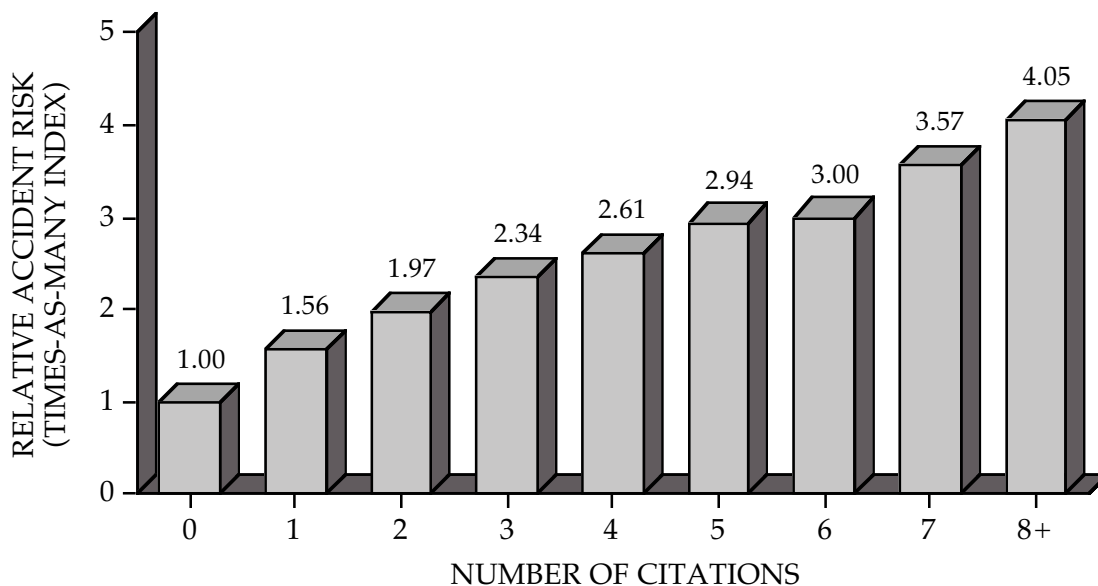


Figure 10. Relative accident risk by number of total citations during a concurrent 6-year period (1993-98).

### Conclusions

- As was the case with the nonconcurrent data, the concurrent results indicate that drivers with successive driver record entries are at a greater risk of accident involvement than are drivers with fewer or no driver record entries.
- As was the case with the nonconcurrent data, a sizable number of drivers in the worst citation groups remain accident-free.
- The relationships between citations and accidents for concurrent data are stronger than those for nonconcurrent data, as evidenced by the higher correlation coefficients for the former. This finding is to be expected because concurrent data are measured during a common time frame and therefore are influenced by a more similar set of external causal factors than are nonconcurrent data.

Table 58

Rate of Total Accidents by Number of Total Citations  
Accumulated during a Concurrent 6-Year (1993-98) Period

Total citations (1993-98)	Number of drivers	Mean accident rate (1993-98)	Times-as-many accidents (1993-98)	% accident-free drivers (1993-98)
0	96,712	0.207	1.00	82.35
1	43,002	0.323	1.56	73.63
2	20,445	0.407	1.97	68.18
3	10,557	0.485	2.34	62.93
4	5,751	0.541	2.61	60.11
5	3,243	0.609	2.94	56.89
6	1,934	0.622	3.00	55.58
7	1,157	0.739	3.57	50.39
8+	2,035	0.839	4.05	47.81

Note: Pearson correlation coefficient between total citations and total accidents = .213 ( $p < .0001$ ).

Table 59

Rate of Total Accidents by Number of Total Citations (Excluding TVS Dismissals)  
Accumulated during a Concurrent 6-Year (1993-98) Period

Total citations (1993-98)	Number of drivers	Mean accident rate (1993-98)	Times-as-many accidents (1993-98)	% accident-free drivers (1993-98)
0	117,256	0.236	1.00	80.19
1	35,136	0.347	1.47	72.23
2	15,052	0.427	1.81	67.07
3	7,516	0.498	2.11	62.60
4	3,879	0.541	2.29	60.43
5	2,287	0.586	2.48	58.15
6	1,370	0.637	2.70	56.35
7	825	0.733	3.11	50.55
8+	1,515	0.792	3.36	49.44

Note: Pearson correlation coefficient between total citations and total accidents = .177 ( $p < .0001$ ).

Table 60

Rate of Total Accidents by Number of Countable Citations  
Accumulated during a Concurrent 6-Year (1993-98) Period

Countable citations (1993-98)	Number of drivers	Mean accident rate (1993-98)	Times-as-many accidents (1993-98)	% accident-free drivers (1993-98)
0	107,818	0.216	1.00	81.64
1	43,087	0.347	1.61	71.98
2	18,025	0.451	2.09	65.40
3	8,193	0.540	2.50	60.09
4	3,906	0.613	2.84	56.37
5	1,932	0.697	3.23	52.17
6	894	0.774	3.58	48.55
7	476	0.860	3.98	46.22
8+	505	1.057	4.89	40.20

Note: Pearson correlation coefficient between countable citations and total accidents = .212 ( $p < .0001$ ).

Table 61

Rate of Total Accidents by Number of Total Moving  
Citations Accumulated during a Concurrent 6-Year (1993-98) Period

Total moving citations (1993-98)	Number of drivers	Mean accident rate (1993-98)	Times-as-many accidents (1993-98)	% accident-free drivers (1993-98)
0	111,927	0.223	1.00	81.16
1	42,242	0.354	1.59	71.51
2	16,944	0.460	2.06	64.98
3	7,301	0.538	2.41	60.47
4	3,428	0.636	2.85	55.34
5	1,561	0.695	3.12	52.53
6	707	0.880	3.95	46.53
7	370	0.965	4.33	41.62
8+	356	0.980	4.39	42.42

Note: Pearson correlation coefficient between total moving citations and total accidents = .204 ( $p < .0001$ ).

#### SECTION 4: STRATEGIES FOR TARGETING HIGH-RISK DRIVERS

##### What Strategies are Useful in Targeting High-Risk Drivers?

As demonstrated in the prior sections of this report, drivers with a previous history of traffic citations and accidents are, on the average, more likely to be involved in subsequent accidents than are drivers with clean records. But it has also been noted that the ability to predict exactly which individuals will be involved in accidents during a specific time interval is extremely limited. This makes it difficult to develop countermeasures that would substantially reduce the statewide accident rate.

Targeting violation repeaters. One possible approach to countermeasure development would be to target accident and violation repeaters. This strategy assumes that the majority of traffic accidents are caused by a relatively small percentage of “deviant” and “accident prone” drivers. Kuan and Marsh (unpublished note, 1981) developed a mathematical model for allocating multiple-vehicle accidents to drivers in different prior-record groups, making it possible to determine what percentage of accidents would be prevented if all “bad” drivers could somehow be removed from the highway or otherwise rendered “accident-proof” (see Appendix note describing the Kuan-Marsh method).

Figure 11 illustrates the impact of a hypothetical countermeasure strategy that would use prior 2-year total citation record to determine which drivers should be targeted.

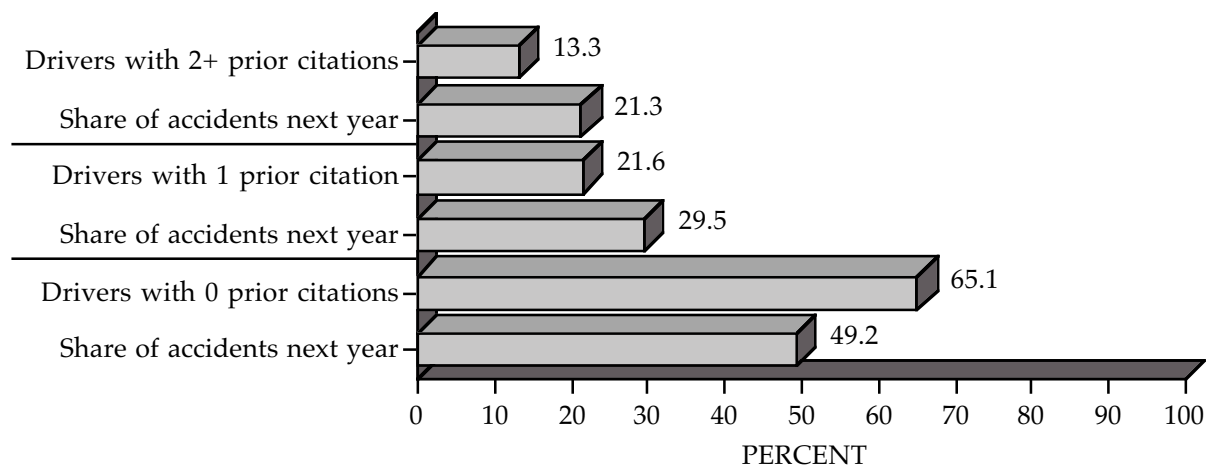


Figure 11. Percentage of total accidents in the next year (1998) involving drivers with different prior 2-year (1996-97) total citations.

An examination of the figure yields the following:

- If all drivers with two or more total citations (13.3% of the sample) were effectively removed from the road, 21.3% of the next year's accidents would potentially be prevented.
- If all drivers with just one total citation (21.6% of the sample) were also removed from the road, another 29.5% of the next year's accidents would be potentially prevented.
- If only drivers who were conviction-free (65.1% of the sample) were allowed to continue driving, at least 49.2% of all accidents would still occur.

Targeting accident-repeaters. Figure 12 displays the probable impact of a hypothetical countermeasure strategy that would keep the accident-repeater from driving.

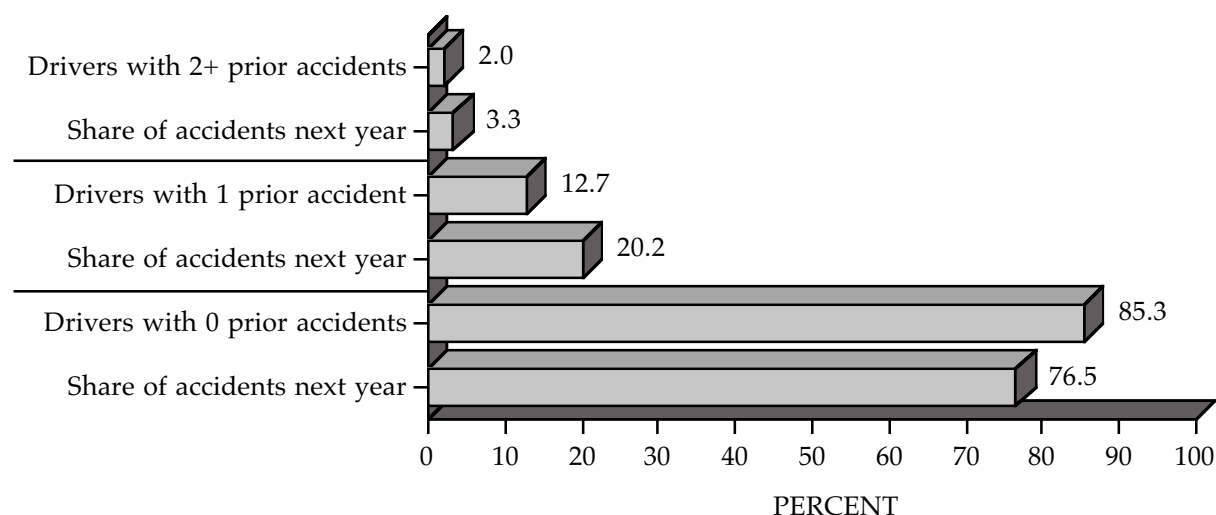


Figure 12. Percentage of total accidents in the next year (1998) involving drivers with different prior 2-year (1996-97) total accidents.

Figure 12 illustrates the following:

- Removal of all drivers with two or more accidents in 2 years (2.0% of the sample) from the road would potentially prevent 3.3% of the next year's accidents.
- Additionally removing drivers with just one accident (12.7% of the sample) would potentially prevent another 20.2% of the next year's accidents.
- If only drivers who were accident-free during the prior 2 years (85.3%) were allowed to continue driving, at least 76.5% of the next year's accidents would still occur.

Although the ratio of accidents prevented to drivers removed is higher for the strategy based on accidents than it is for the strategy based on convictions, the net number of accidents prevented by the former is less. Fewer accidents are potentially preventable by targeting accident-involved drivers because accidents occur much less frequently than do traffic convictions. For example, only 2.0% of drivers have more than one accident in 2 years, while 13.3% have more than one conviction. In short, although accident repeaters are more likely than conviction repeaters to be involved in future accidents, there are so few of them that the net accident savings from removing those drivers from the road is much smaller.

Targeting the negligent-operator. The results displayed earlier suggest that prior neg-op points relate more strongly to subsequent accidents than do either prior accidents or prior convictions alone. Figure 13 indicates that using prior neg-op points to target drivers for removal from driving would slightly increase the number of potentially preventable accidents above the number saved by targeting only violation-repeaters.

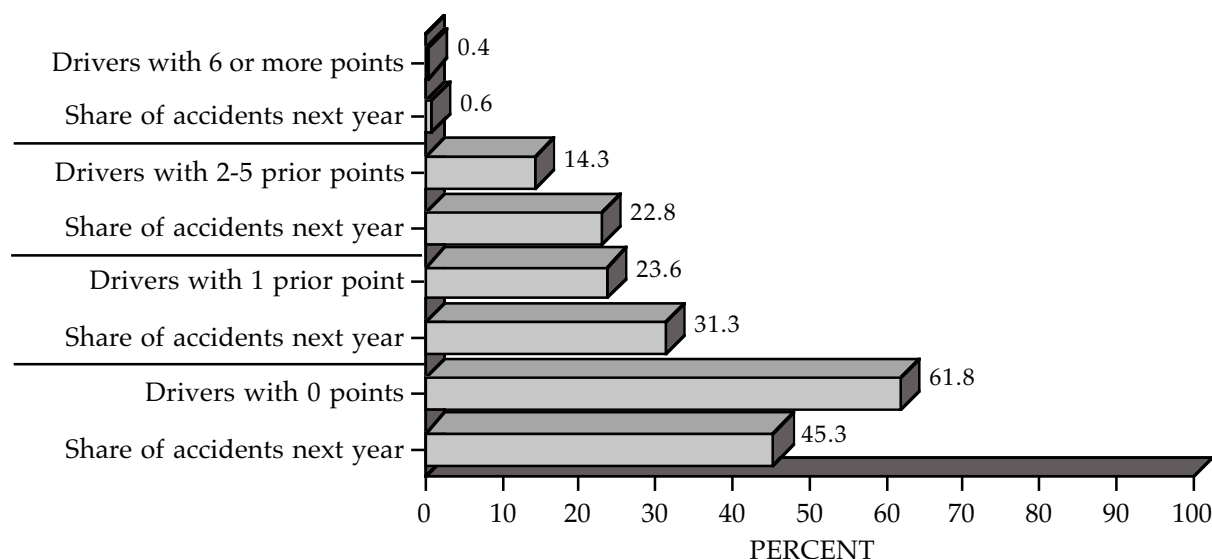


Figure 13. Percentage of total accidents in the next year (1998) involving drivers with different prior 2-year (1996-97) negligent operator points.

For example, Figure 13 offers the following conclusions:

- The 38.2% (100.00% – 61.8%) of drivers with one or more points account for 54.7% (100.00% – 45.3%) of the next year's accidents. They have approximately 1.43 (54.7/45.3) times as many accidents as would be expected from their representation in the driver population.
- Removal of statutorily defined neg-ops (six or more points in 2 years) would potentially eliminate 0.6% of the next year's accidents, 1.5 (0.6/0.4) times what would be expected from their 0.4% representation in the driver population.

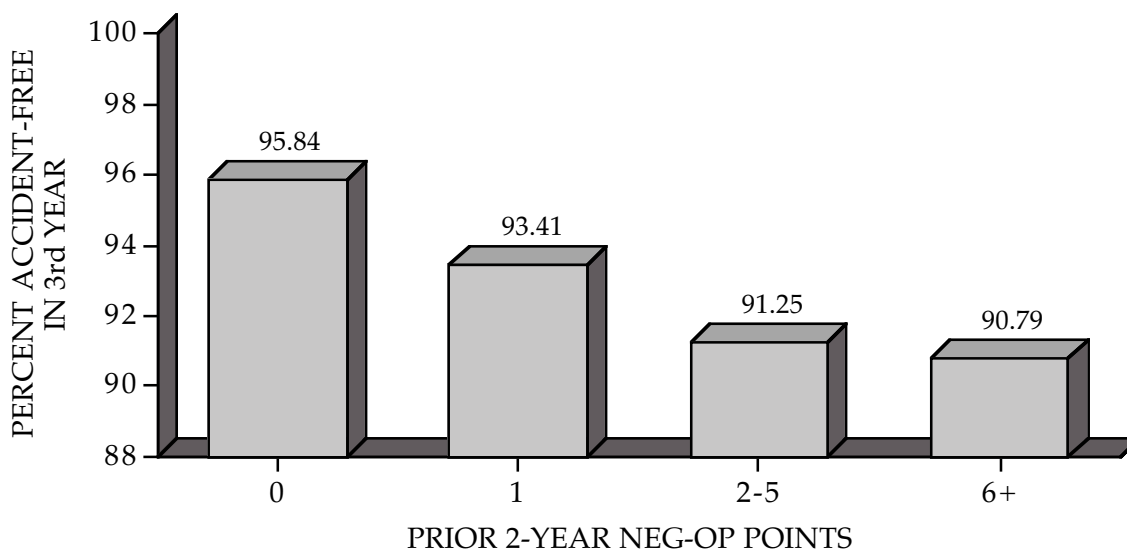


Figure 14. Percentage of drivers accident-free during 1998 by negligent-operator point count for the prior 2 years (1996-97).

It should be kept in mind that, although removing drivers with one or more neg-op points in 2 years would potentially eliminate the majority of accidents in the next year, the vast majority of drivers removed would not have had an accident if they had been allowed to continue driving. As Figure 14 illustrates, the great majority of drivers with one or more neg-op points in the first 2 years are accident-free in the third year.

#### Policy Implications

What implications do the above facts have for the development of optimum accident countermeasures and driver control strategies?

- First, the finding that accident and conviction repeaters in a prior period are as a group much more likely than other drivers to be involved in subsequent accidents justifies them for driver control actions.
- Second, this finding supports the use of prior driving record in graduating auto insurance premiums.
- Third, under any of the three countermeasure strategy examples discussed above, the majority of accidents would still occur if the worst driver-record group were removed from the road, because most accidents involve drivers with no more than one prior incident on the driving record. Dramatic reductions in accidents would require modification of other components of the transportation system and expansion of driver improvement/driver control measures to a larger proportion of drivers.

The reader will note that the analyses presented so far in this report examine only or two-variable relationships (e.g., subsequent accidents by prior accidents) or three-variable relationships (e.g., subsequent accidents by prior citations and prior accidents). The formulation of an optimum risk prediction system, however, should examine the unique contributions of interactive effects of a set of variables related to driver performance (sex, age, area of residence, violation type, etc.). Such a set of analyses, using multiple regression as the primary statistical tool, is presented in the following section.

## SECTION 5: ACCIDENT PREDICTION MODELS

### Analytical Procedures

In the previous sections, accident risk relativities were expressed as a function of either one or two driver record variables. Because accident risk is a complex function of many variables, strategies for optimally estimating and predicting individual accident risk must be multidimensional in form. There are several techniques for doing this; one of the most powerful and frequently used techniques is negative binomial multiple regression. In the case of the accident criterion, negative binomial multiple regression analysis produces an equation that gives the most accurate possible prediction of individual accident involvement rate (number of accidents), using an optimum linear composite of the mean values of the various independent variables (e.g., gender, age, and prior driving record). The regression equation can also be used to predict along a continuous scale whether or not an individual driver will be involved in a future accident.

Another commonly used statistical modeling technique is multiple logistic regression. In contrast to the continuous criterion scale in negative binomial regression, the criterion scale in logistic regression allows for a criterion value of 0 or 1 (e.g.,  $Y = 1$  if a driver is involved in one or more accidents; otherwise  $Y = 0$ ). The logistic regression model shares a common feature with a more general class of linear models in that a function of the binary response variable is assumed to be linearly related to the explanatory (independent) variables. Use of a logistic regression model allows for the computation of relative odds, called an odds-ratio, of an accident involvement. For example, if men and women (the referent group) were compared on relative accident risk, an odds-ratio greater than 1 would indicate that men are a higher accident risk, a value of 1 would indicate that both sexes are of equal accident risk, and a value less than 1 would indicate that men are a lower accident risk.

In this section, results for both negative binomial and logistic regression analyses are presented. Two multiple regression equations were computed.

The first is a simple additive (or “main effects”) negative binomial regression model for predicting subsequent accident involvement from prior driver record variables. Backward elimination regression analysis was employed for identifying which combination of variables from the potential predictor pool provided the most accurate



equation for predicting the criterion measure. Only those variables that were statistically significant were included in the final model.<sup>1</sup>

The second model originates from a study by Gebers and Peck (2003a) who included in a logistic regression analysis an evaluation of selected interactions between driver age and prior total citations and prior total accidents. The rationale for testing the presence of the selected interactions was to assess whether young drivers aged 18 through 21, or drivers aged 70 or older, exhibit a steeper increase in future accident risk at successive prior accident or prior citation levels as compared to drivers in general. The existence of one or more significant interactions could be used as evidence to justify developing customized traffic safety programs tailored to driver age.

### Results

Table 62 summarizes the additive negative binomial multiple regression analysis for estimating 3-year (1996-98) total accidents for a random sample of 184,836 California drivers.

Before discussing these results, some clarification is in order concerning the procedures used. The reader will note that while four age groups were compared, Table 62 shows only three categories of age groups. The deletion of one category, identified as the referent group of drivers aged 24 and under, is required to prevent a singular matrix (i.e., the problematic situation in which a variable or category is a perfect linear function of the other categories). No information is lost in doing this because the regression coefficient for each predictor variable reflects the difference in the relative accident risk between the age groups and the referent group.

Table 62 shows that the test of this model against that of a constant-only model (without any predictor variables included) was statistically significant ( $\chi^2 = 3,605.09$ ,  $p < .0001$ ). This result indicates that the equation consisting of the set of predictor driver record variables reliably estimated the total accident involvement risk of the drivers in the sample.

Table 62 also shows the regression coefficients and  $\chi^2$  for each predictor variable. The  $\chi^2$  statistic simultaneously tests the significance of the regression coefficients in which the effect of each variable in the model is adjusted for the effects of all other variables. The results of the individual  $\chi^2$  tests indicate that each independent variable reliably estimated subsequent accident risk. The directions (signs) of the regression coefficients indicate that increased accident involvement is associated with the following:

- Increased prior citation frequency.
- Increased prior accident frequency.
- Being a man.

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<sup>1</sup> A test of statistical significance allows one to determine if the probability that an observed parameter estimate was found to be different from zero is due to chance alone. If the probability is sufficiently small, it is concluded that the difference from zero is "real." For the backward elimination regression analyses, a difference was considered to be statistically significant when the probability of a difference occurring by chance was less than 1 in 10 ( $p < .10$ ).

- Having a commercial drivers license (which are mostly held by high-mileage professional drivers).
- Having a medical condition on record.
- Being young.
- Having a physician referral for low visual-acuity on record.

Table 62

Summary of Multiple Negative Binomial Regression Analysis for  
Estimating 3-Year (1996-98) Total Accidents  
( $n = 184,836$ )

Predictor variable	Regression coefficient	Standard error	$\chi^2$	$p$
Constant	-1.8521	0.0180	10,562.90	< .0001
3-year (1993-95) total citations	0.1255	0.0049	658.83	< .0001
3-year (1993-95) total accidents	0.2915	0.0124	550.68	< .0001
Gender	0.1210	0.0131	85.88	< .0001
Class of license	0.4341	0.0276	247.15	< .0001
P&M condition on record	0.4394	0.0398	121.68	< .0001
Age (referent group: 24 & under)				
25-49	-0.2745	0.0176	242.09	< .0001
50-69	-0.4522	0.0219	426.49	< .0001
70 & above	-0.3579	0.0315	129.50	< .0001
DL-62 (vision referral) on record	0.1503	0.0735	4.19	0.0408
-----				
-2 log likelihood for intercept only = 161,477.13				
-2 log likelihood for intercept and covariates = 157,872.04				
$\chi^2$ for covariates = 3,605.09, $p = < .0001$				

Using the model in Table 62, one can obtain risk of total crash involvement (risk relativity),  $\lambda_{iv}$  in terms of the constant parameter,  $\alpha$ , and the regression coefficients,  $\beta$ . That is, the regression coefficients in Table 62 were converted into ratios of risk relativities through exponential transformation. In other words,  $RR = \lambda_{i1} / \lambda_{i0} = \exp(\alpha_i + \beta) / \exp(\alpha_i) = \exp(\beta) = e^\beta$ .

The relative risk ratio estimates obtained from the coefficients in Table 62 are presented in Table 63.

Table 63

Relative 3-Year (1996-98) Total Accident Risk (Risk Ratio Estimate)  
for Main Effects Negative Binomial Multiple Regression Model  
( $n = 184,836$ )

Predictor variable	Risk-ratio
3-year (1993-95) total citations	
0 vs. 1	1.13
0 vs. 2	1.29
0 vs. 3	1.46
0 vs. 4	1.65
3-year (1993-95) total accidents	
0 vs. 1	1.34
0 vs. 2	1.79
0 vs. 3	2.40
Gender	
Women vs. men	1.13
Class of license	
Commercial vs. noncommercial	1.54
Physical & mental condition on record	
No vs. yes	1.55
Age	
24 & under vs. 25-49	0.76
24 & under vs. 50-69	0.64
24 & under vs. 70 & above	0.70
DL-62 (vision referral) on record	
No vs. yes	1.16

*Note:* Predictors listed are significant at  $p < .05$ . Chi-square for entire main effects model is 3,605.09 ( $p < .0001$ ).

In a manner similar to the times-as-many index presented earlier, the relative risk ratio refers to the relative risk of being accident involved, but as a function of a predicted driver-record category. For example, an examination of selected relative risk ratios in Table 63 conveys the following:

- Drivers with one prior citation are 1.13 times as likely to be involved in a subsequent accident as are citation-free drivers.
- Drivers with four prior citations are 1.65 times as likely to be involved in a subsequent accident as are citation-free drivers.

- Drivers with one prior accident are 1.34 times as likely to be involved in a subsequent accident as are accident-free drivers.
- Drivers with three prior accidents are 2.40 times as likely to be involved in a subsequent accident as are accident-free drivers.
- Men drivers are 1.13 times as likely to be involved in a subsequent accident as are women drivers.
- Drivers with a commercial license are 1.54 times as likely to be involved in a subsequent accident than are drivers without a commercial license.

As stated above, the results from the regression model presented in Tables 62 and 63 are additive (main effects) models. Both models fail to account for variation due to a moderated or interactive relationship that may exist between the driver record variables.

The contribution of interactions was assessed by Gebers and Peck (2003a), and their results are reproduced here. Gebers and Peck evaluated selected interactions between driver age and prior total citations and prior total accidents. The rationale for testing the presence of the selected interactions was to assess whether young drivers aged 18 through 21, or older drivers aged 70 or above, exhibit a steeper increase in future accident risk at successive prior accident or prior citation levels as compared to drivers in general. The existence of one or more significant interactions could be used as evidence to justify developing customized traffic safety programs tailored to driver age. Before discussing the results, some clarification is in order concerning the procedures used in constructing and evaluating the interaction models. Total citations and total accidents were entered into the equation as continuous variables along with the appropriate two-way age-by-citations and age-by-crashes product terms. To reduce multi-collinearity (i.e., statistical problems emanating from intercorrelations among independent variables), the total citations and total crash variables were first “centered” by subtracting the respective sample’s citation and crash means from each subject’s observed citation and crash counts.

The variable driver age is comprised of three categories even though the output shows only two categories. The two displayed categories are drivers aged 18 through 21 and drivers aged 70 and above. Drivers aged 22 through 69 served as the omitted referent category (see the discussion in the prior section summarizing the results for the main effects analysis for the rationale of the omitted referent group in regression analysis).

The reader will note from the above discussion that drivers under the age of 18 have been omitted. Since licensed California drivers under the age of 18 are already subjected to age-tailored license restrictions and post license controls under California’s Graduated Licensing Program, these drivers have been excluded from the interaction model.

In formulating the interaction regression models, a modified backward elimination procedure was used in which the interactions were forced into the equation and then eliminated one at a time until a likelihood ratio test with a significant value of  $p < .05$

was obtained. The goal of such modeling is to find the reduced model with the fewest predictors that still closely mimics the observed value of the outcome variable.

Results of the backward elimination likelihood ratio tests comparing models with and without interactions indicate that the model consisting of both the age-by-citations interaction and the age-by-total accidents interaction was the model that most closely predicted or “mimicked” the observed value of the subsequent total crash criterion.

Table 64 presents a summary of the nonconcurrent 6-year (1993-95; 1996-98) multiple logistic regression equation for predicting subsequent total accident involvement from the interaction model.

Table 64

Summary of Nonconcurrent 6-Year (1993-95; 1996-98) Multiple Logistic Regression Equation for Predicting Total Crash Involvement  
( $n = 187,313$ )

Predictor variable	Regression coefficient	Standard error	Wald $\chi^2$	$p$
Intercept	-1.9202	0.0075	65,945.55	< .0001
Total crashes	0.3336	0.0157	450.48	< .0001
Total citations	0.1807	0.0060	902.96	< .0001
Age (referent group: 22-69)			216.60	< .0001
18-21	0.4115	0.0280	216.24	< .0001
70 & above	0.0514	0.0367	1.97	.1608
Age by prior total crashes			15.55	.0004
Age 18-21 by prior total crashes	-0.1733	0.0478	13.14	.0003
Age 70 & above by prior total crashes	0.0850	0.0670	1.61	.2048
Age by prior total citations			52.07	< .0001
Age 18-21 by prior total citations	-0.0673	0.0155	18.80	< .0001
Age 70 & above by prior total citations	0.3267	0.0584	31.25	< .0001

-2 log likelihood for intercept only = 145,829.87

-2 log likelihood for intercept and predictors = 143,798.23

$\chi^2$  for predictors only = 2031.64,  $p < .0001$

Although the existence of the statistically significant interactions focuses attention on the interpretation of the interactions rather than on the main effect terms, the nature of regression requires that all lower-order main effect terms be included in the models containing corresponding higher-order interaction terms. Specifically, as displayed in Table 64, the model evaluates the contribution of a two-way interaction between driver age and prior total citations and a two-way interaction between driver age and prior total accidents. As displayed in the table, the existence of the two-way interactions requires the inclusion of all lower-order age, total citations, and total accidents main-effect terms.

While the full model containing the two-way interactions and main effects is statistically significant ( $\chi^2 = 2,031.64, p < .0001$ ), the question of whether the existence of the various interactions reliably contributes to the prediction of subsequent total accident involvement is assessed by the aforementioned backward elimination test utilizing the likelihood ratio statistic. The results of the backward elimination tests indicate that eliminating either one or both of the two-way age by prior driving record interactions resulted in a statistically significant ( $p < .01$ ) loss in model fit or prediction accuracy. Therefore, the interaction model which best fits these data is one containing both the age by prior total accidents interaction and the age by prior total citations interaction.

The statistical significance of the interactions indicates that the relationship between prior total accidents and subsequent total accidents and between prior total citations and subsequent total accidents was not the same for the different age categories. To visualize and gain insight into the effect of these interactions on the magnitude and shape of the subsequent total accident risk curves, it is necessary to produce plots of the curves by application of the appropriate main effect and interaction product terms in the equation.

Figure 15 illustrates the subsequent 3-year total log odds of total accident involvement by prior 3-year total accidents and driver age. Figure 16 illustrates the subsequent 3-year total log odds of total accident involvement by prior 3-year total citations and driver age. A constant of 4 has been added to the original log odds values to eliminate negative log odds values and, thereby, ease reader interpretation.

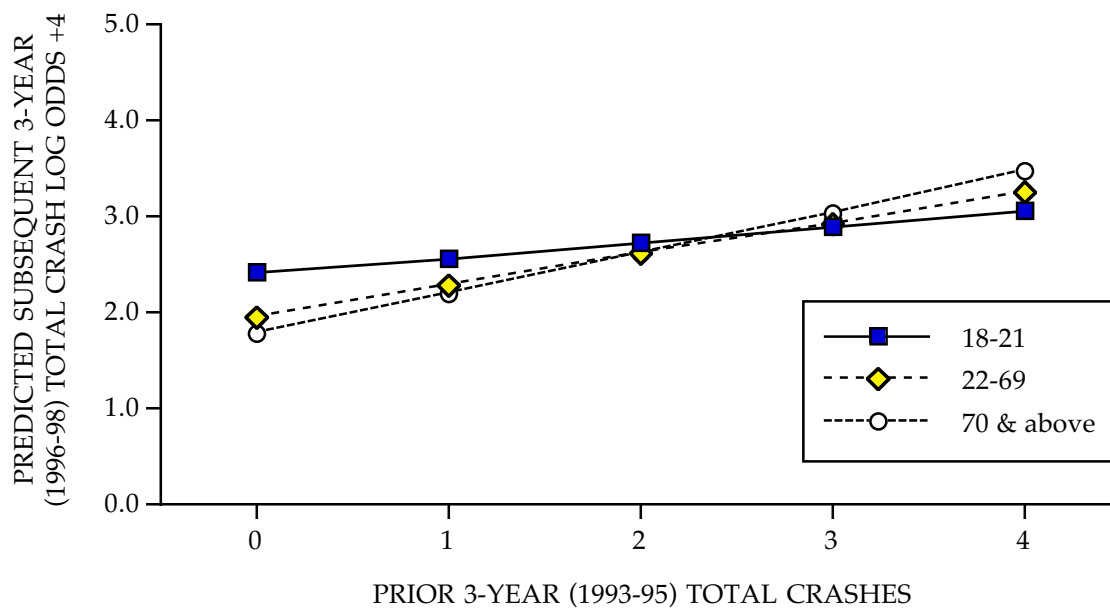


Figure 15. Predicted subsequent 3-year (1996-98) total crash log odds +4 by age group and number of prior 3-year (1993-95) total crashes.

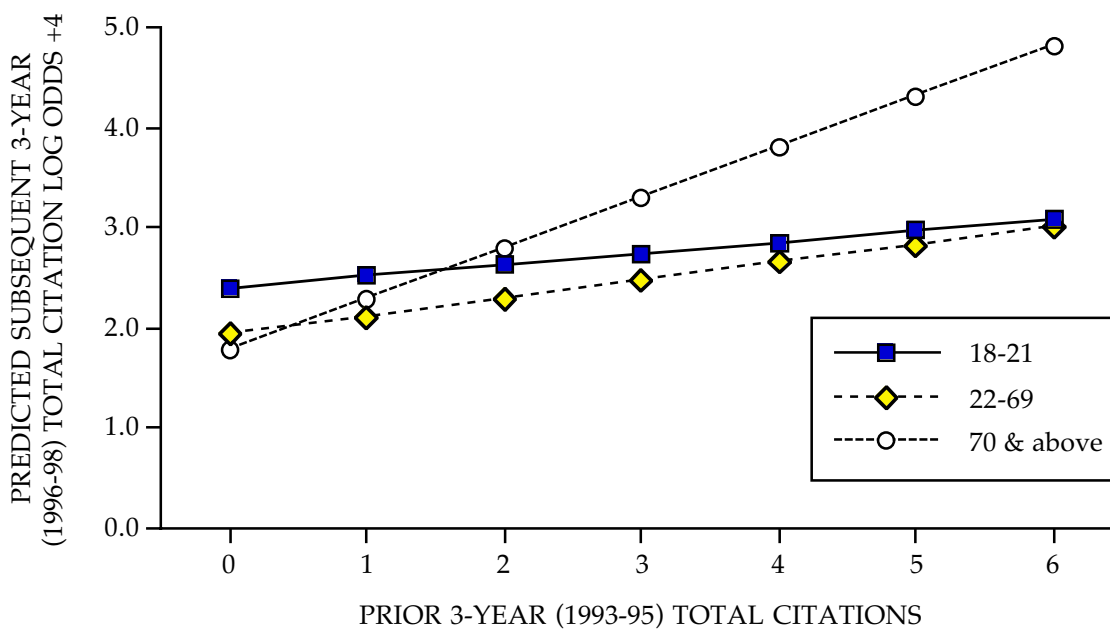


Figure 16. Predicted subsequent 3-year (1996-98) total citation log odds +4 by age group and number of prior 3-year (1993-95) total crashes.

As Figure 15 shows, the odds of subsequent total accident involvement for drivers aged 18-21 exceed the odds of subsequent total accident involvement for drivers aged 22-69 and for drivers aged 70 and above through about two prior total-accident involvements, and the odds for the three groups are fairly similar at three and four prior total-accident involvements.

An examination of the age by prior total citations interaction illustrated in Figure 16 indicates that through four prior total citations, drivers aged 18-21 exhibit an odds of subsequent total accident involvement consistently higher than the odds of subsequent total accident involvement for drivers age 22-69. At zero through two prior total citations, the odds of subsequent total crash involvement associated with drivers age 18-21 are higher or approximately equal to the odds of subsequent total accident involvement associated with drivers 70 and above.

Figure 16 indicates that the odds of subsequent accident involvement for drivers aged 70 and above are lower or approximately equal to drivers age 22-69 through about one prior total citation. However, at around the two prior total citations level, the odds of subsequent total accident involvement for drivers aged 70 and above exceed the odds of subsequent total accident involvement for drivers 18-21 and for drivers aged 22-69.

#### Conclusions

- Accident risk is a complex function of many variables, and strategies for predicting individual accident risk must be multidimensional in form.
- Increased accident involvement was demonstrated to be associated with increased prior citation and accident frequency, possessing a commercial driver license, being young, being a man, having a medical condition on record, and having a physician referral for low visual-acuity on record.
- The results from the interaction model examining subsequent total accident involvement for young and older drivers with differing counts of prior driver record incidents warrants an examination of the viability of applying age-mediated traffic safety treatments to high-risk driver groups currently not receiving any form of driver safety intervention.

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## APPENDIX

### DESCRIPTION OF VARIABLES USED IN DATA ANALYSES

#### Total Accidents

Accident data presented in this report represent reported accidents only. For the time periods of the data presented in this report, California Vehicle Code (CVC) Section 16000 required the driver of every motor vehicle involved in an accident resulting in damage to property of either party in excess of \$500 or in bodily injury or death of any person to submit a written report to the Department of Motor Vehicles. (Effective January 1, 2003, the monetary reporting requirement was raised to \$750.) Failure to file a report under the above conditions will result in suspension of the driving privilege. Accidents involving injury or fatality must also be reported to the DMV by the California Highway Patrol.

Throughout this report, use of the term “accidents” actually means “accident involvements.” More than one driver can be (and indeed usually is) involved in any given accident. If a driver in the 1% random sample collided with another driver from within the same sample, this would be counted as two involvements—one for each driver—although both involvements would represent the same accident. If a driver in this sample collided with a driver outside of the sample, the accident would count as one involvement.

#### Fatal/Injury Accidents

These are accidents resulting in death or injury. A fatal accident results in the death of one or more persons within 30 days of the accident. An injury accident results in a severe wound or other visible injury to, or complaint of pain from, one or more persons.

#### Responsible Accidents

These are accidents in which the driver is indicated by the investigating officer to have been at least partly responsible.

#### Total Citations

The citation count includes convictions, failures to appear in court (FTAs), and traffic violator school (TVS) dismissals in the defined time period (based on violation date). A citation that is dismissed conditional upon the offender’s completion of TVS is not an actual conviction. Each citation incident is counted as only one conviction, one FTA, or one TVS dismissal, even if there are multiple violations (e.g., when a driver is cited for speeding and failing to stop for a red light on one “ticket”). Total citations are also presented after excluding TVS dismissals.

#### Countable Citations

These are countable convictions and TVS dismissals. Countable citations are usually for safety-related violations (e.g., speeding, right-of-way, DUI, and hit-and-run).

#### Moving Citations

These are convictions and TVS dismissals for safety-related violations, excluding the more serious violations (e.g., DUI and hit-and-run).

### Major Citations

These are convictions for serious violations (e.g., DUI and hit-and-run).

### Negligent-Operator Points

In determining neg-op points in California, one point is entered on the driving record for each moving-violation conviction (e.g., speeding, unsafe turns), except those involving “major” offenses such as driving under the influence of alcohol/drugs, reckless driving, and hit-and-run. The latter convictions count two points each. If a violation occurs while a licensed commercial operator is driving a commercial vehicle or transporting hazardous material, then the normal point count for the conviction is multiplied by 1.5 (i.e., a one-point conviction becomes 1.5 points, and a two-point conviction becomes three points). An accident for which the driver is deemed at least partly responsible counts one point. To maintain consistency with prior driver record study reports, all accidents were assigned one point. As defined by CVC Section 12810.5, drivers with a class 3/C (personal auto or pickup truck) driver license are defined as neg-ops when their driver records contain four or more points in 1 year, six or more points in 2 years, or eight or more points in 3 years.

### TVS Citation Dismissals

These are traffic citations that were dismissed contingent upon completion of a state-certified TVS program as defined in CVC Section 42005.

### Class of License

This is the primary class of driver license as recorded on an individual’s driving record. In California, the classes of driver licenses are the following:

A – May drive any vehicle or combination of vehicles (except motorcycles).

B – May drive large, multi-axle vehicles and autos.

C – May drive small buses, small trucks, and autos (regular driver license).

M1 – May drive motorcycles only.

M2 – May drive small motorcycles only.

### Physical or Mental Code

This indicates the presence or absence of a medical condition.

### DL-62 Code

This is the presence or absence of a physician referral (DL-62) for low visual acuity.

### Kuan-Marsh Method of Counting Accidents

The need for such a model arose because the Department’s records, being driver-based, contain the number of accident involvements (i.e., drivers involved in accidents) rather than the number of accidents. Most traffic accidents involve more than one driver (an average of approximately 1.7 drivers per accident). One might be tempted to adjust by dividing the number of involvements for each group’s share of accidents by 1.7 and

consider that number as the group's share of accidents. However, such an adjustment would provide an underestimate of the number of accidents for each group because the figures for the number of involvements originate from a random sample. Hence, they represent fewer than 1.7 involvements per accident because the probability that more than one member of the same sample will be involved in the accident is low, unless the sample is extremely large.

The Kuan-Marsh method involves partitioning involvements into non-overlapping subsets and allocating them to a group of drivers so that only one involvement per accident is counted. The method of allocation is to consider each involvement an accident, and to assign all accidents in which one of these drivers was involved to the group with the worst prior record, minus a correction for double-counting accidents in which two or more of this group were involved. Then all accidents in which one of the next-worst-record group was involved, and no members of the worst group were involved, are assigned to the group with the next worst record, minus a correction for double-counting accidents in which two or more members of that group were involved. This process continues until the best group is allocated only single-vehicle accidents of members of that group and accidents in which only other drivers in the best group were involved. This is somewhat similar to allocating accidents by responsibility, assuming that, of drivers involved in an accident, the driver with the worst record was responsible for that accident.